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DROUGHT FEEDING STUDIES WITH CATTLE

6. SORGHUM SILAGE, WITH AND WITHOUT UREA, AS A DROUGHT FODDER FOR CATTLE IN LATE PREGNANCY AND EARLY LACTATION

By J. W. Ryley, B.V.Sc. *

SUMMARY

Three groups, each of 10 pregnant Hereford heifers, were confined in bare yards when their mean stage of gestation was 175 days. All groups received a basal ration of sorghum silage *ad lib.* One group received no supplement, while the other two groups were fed a supplement of 1.5 oz and 2.5 oz of urea per head per day respectively. The experiment terminated after 24 weeks, when the mean stage of lactation of animals suckling calves was 62 days.

Heifers receiving no supplement lost an average of 150 lb body-weight prior to calving. This body-weight loss was significantly higher than those of 79 lb and 42 lb in the two groups receiving 1.5 oz and 2.5 oz of urea per head per day respectively. The average body-weight loss for those animals suckling calves at the conclusion of the experiment was 385 lb in the group receiving no supplement. The body-weight losses for comparable animals in the groups receiving 1.5 oz and 2.5 oz of urea per head per day were 286 lb and 236 lb respectively.

Urea supplementation increased silage consumption. The mean daily consumption of dry matter per head in each group was: no supplement, 6.3 lb; 1.5 oz urea, 9.0 lb; 2.5 oz urea, 10.2 lb.

The average birth weight of the calves born to heifers in the group receiving no urea was 48.4 lb and was significantly lower than that of 55.6 lb in the calves born to heifers in the group receiving the higher level of urea.

Deaths of 4 calves in the non-supplemented group were attributed to the experimental treatment. No calves died in the group receiving 1.5 oz of urea, while there was one death in the group supplemented with 2.5 oz of urea.

The average body-weight gain in calves from birth to 28 days of age was 9.4 lb in the non-supplemented group and 23.3 lb and 16.4 lb in the groups supplemented with 1.5 oz and 2.5 oz of urea respectively.

Milk production was obtained over a 24-hr period at the conclusion of the experiment by hand-milking the animals after oxytocin injections. The yield was significantly higher in the two groups receiving urea than in the non-supplemented group.

The overall incidence of both dystokia and retained placenta was 15 per cent. There were no significant differences between groups.

At the conclusion of the experiment, there were no significant differences among group means in serum total protein, albumin and globulin; plasma chloride, sodium and potassium; and blood haemoglobin and packed cell volume. After 24 weeks on silage the values in all groups for serum total protein and plasma sodium were significantly lower than initial values.

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I. INTRODUCTION

Previous papers in this series have reported results on the use of native pasture hay (Morris 1958*a*), sorghum silage with and without urea (Morris 1958*b*) and restricted rations of sorghum grain (Morris 1958*c*; Ryley, Gartner, and Morris 1960) as drought fodders for non-pregnant heifers. These experiments, together with those of Southcott and McClymont (1960*a*, 1960*b*) on the feeding of hay-grain and all-grain rations to steers and non-pregnant heifers, have provided information on the survival requirements of these classes of animals, fed under pen conditions on fodders that could be conserved on many beef cattle properties in Queensland. As heifers must be considered as the potential breeding herd, it was most desirable to obtain these data before studying the survival requirements of other classes of cattle.

From survey data collected by the Queensland Department of Agriculture and Stock, it is apparent that the highest mortality in cattle during droughts occurs in pregnant and lactating animals. This is due to the higher nutritional requirements in late pregnancy and in lactation, together with the additional stress of calving. The next stage in the series of investigations on drought feeding at the Animal Husbandry Research Farm, Rocklea, Brisbane, has been concerned with the survival requirements of pregnant heifers and lactating cows and their calves.

The aim of the experiment reported in this paper was to investigate the value of sorghum silage, comparable in composition to that which has been produced in western Queensland, as a fodder for cattle in late pregnancy and early lactation. The silage was fed either as the sole ration or supplemented with two levels of urea. Data were obtained on changes in body-weight, voluntary silage consumption, milk production and incidence of dystokia and retained placenta in heifers, and on birth weight, mortality and growth rate of their calves. Determinations were made of total serum protein, albumin and globulin; plasma chloride, sodium and potassium; and blood haemoglobin and packed cell volume of heifers and calves.

II. MATERIALS AND METHODS

(i) *Sorghum Silage.*—The sorghum used in this experiment (*Sorghum vulgare* var. Sugardrip) was grown at the Animal Husbandry Research Farm on land that had been under cultivation for a number of years. No fertilizer treatment was applied. The crop was harvested with a forage harvester and chopper 106-118 days after planting. At this stage it was approximately 10 ft high and the seed was in the soft to hard dough stage. It was ensiled over a period of 12 days in a hillside trench silo with a capacity of approximately 240 tons. The method of ensiling and the design of the silo were similar to those described by Morris (1958*b*).

Twenty-two months after ensiling, the trench was opened on a vertical face and silage removed daily for experimental feeding.

(ii) *Experimental Animals.*—Thirty-four dehorned maiden Hereford heifers were selected for mating. They consisted of 27 animals that had been used

9 months previously in the silage feeding experiment described by Morris (1958*b*) and 7 heifers that had not been used previously for experimental work. These two groups were approximately 30 and 20 months of age respectively when mating commenced. Prior to the commencement of mating they had been grazing predominantly *Paspalum dilatatum* pastures. All animals were negative to the serological tests for brucellosis and *Leptospira pomona* prior to mating and also at the commencement of the experiment.

The heifers were hand-mated to a Hereford bull during a period of 48 days. Three heifers returned to service and were re-mated; all others had been allowed one service only. The animals remained on paspalum pasture during the mating period and until one week before the commencement of the experimental treatments.

Two weeks before the experiment was due to commence the animals were examined for pregnancy. From the 32 found to be pregnant, 30 were selected for the experiment. These included 6 of the heifers that had not been used previously for experimental work.

The mean stage of gestation at the commencement of the experiment was 175 days. The mean body-weight gain of all animals from mating to the commencement of the experiment was 169 lb. The animals were in good condition.

To avoid confusion the term "heifers" has been retained throughout this paper, even though after calving, "cows" is more appropriate.

(iii) *Experimental Yards and Facilities.*—The yards and facilities were essentially those described by Morris (1958*a*). A duplicate set of three yards was provided with covered creeps so that the calves only could be supplemented after they had reached four weeks of age.

(iv) *Body-weight.*—The heifers and calves after they were 7 days of age were individually weighed on a cattle-weighing scale with an acuracy of ± 1 lb. The birth weights and 7-day body-weights of the calves were obtained on a weighbridge with an accuracy of ± 0·5 lb.

(v) *Sampling of Silage.*—Silage was removed by a post-hole auger from three sites in the trench before commencement of feeding. A subsample of this silage was used for quality tests and proximate analysis.

A sample for dry-matter determinations was also obtained from the silage fed each day. These oven-dried silage samples were retained and at the conclusion of the experiment subsampled for proximate analysis. As daily residues were not fed back during the last 13 weeks, they were sampled for dry-matter determinations. These dried samples of residues were retained and subsampled at the end of the experiment for proximate analysis.

(vi) *Methods of Chemical Analysis.*—Analytical methods employed were as follows:—proximate analyses of feedstuffs, Association of Official Agricultural Chemists (1955); silage quality tests, Watson and Ferguson (1937); serum protein, albumin and globulin, Gornall, Bardawill, and David (1949); plasma

chloride, sodium and potassium, as described by Morris (1958*c*). Heparinized blood was used for the determination of haemoglobin by the method of Donaldson *et al.* (1951) and packed cell volume (P.C.V.) by essentially the method of Wintrobe (1947). A relative centrifugal force of approximately 2067 *g* was used for obtaining P.C.V.

(vii) *Determination of Milk Production.*—All heifers were segregated from their calves and hand-milked on the last day of the experiment. They were then milked again, in the same group order, 24 hr later. An intravenous injection of 10 I.U. of oxytocin in 10 ml of physiological saline was given to each cow immediately prior to each milking. The volume of milk obtained at the second milking was measured in a graduated measuring cylinder to an accuracy of ± 5 ml.

III. EXPERIMENTAL

(i) *Treatments.*—The 30 pregnant heifers selected for the experiment were confined to the experimental yards for a week immediately prior to the experiment and fed sorghum silage *ad lib.* They were then allotted to three groups of 10 by stratified random allocation on the basis of previous experimental treatment and mating date. The groups were allocated at random to the following experimental treatments:—

Group I: Sorghum silage *ad lib.*

Group II: Sorghum silage *ad lib.* + 1·5 oz urea and 0·14 oz sodium sulphate per head per day.

Group III: Sorghum silage *ad lib.* + 2·5 oz urea and 0·18 oz sodium sulphate per head per day.

The amount of silage fed daily was slightly in excess of intake. For the first 11 weeks of the experiment residues were fed back, the previous day's residue being placed on top of the freshly added silage. For the remaining 13 weeks the residues were weighed, sampled to obtain dry-matter content, and the remainder discarded. The change was made because it was considered that the presence of the previous day's residue may have been affecting voluntary silage intake. This change did not appear to result in increased consumption. The mixed urea and sodium sulphate supplement was sprinkled on the silage in the troughs and then mixed with the upper portion of the silage.

Heifers were removed from the experiment if their calves were born dead or died during the experimental period. This ensured that all animals in the experiment were either pregnant or suckling their calves.

On the first weekly weighing day after calves reached 4 weeks of age they, together with their dams, were transferred, in their respective groups, to the yards containing a creep. The calves were allowed unrestricted access to a mixture of equal parts by weight of lucerne chaff and crushed sorghum grain.

(ii) *Observations and Recordings.*—For the first 11 weeks of silage feeding, the mean daily dry-matter intake was computed from the weekly silage consumption and the average weekly dry-matter content. Thereafter, when residues were

discarded, silage intake was measured daily and daily dry-matter intake calculated from determinations of dry-matter made on the silage as fed and on the residues.

Individual body-weights of the heifers were obtained weekly by weighing at a standard time (7 a.m.-8 a.m.). As the calving period approached all animals were weighed three times weekly and again on the morning of the day after calving. This allowed the pre-calving body-weight to be obtained 0–96 hr prior to parturition and the post-calving weight to be taken 0-24 hr after parturition.

The birth weight of calves was obtained between 6 and 16 hr after birth. Calves born in the morning were weighed in the afternoon and those born during the late afternoon and night were weighed between 7 a.m. and 8 a.m. on the next day. All live calves had dry coats at the time of weighing. Calves were weighed at the same time 7 days later, but thereafter were weighed on the standard weekly weighing days.

On the day prior to the commencement of silage feeding (initial) and at the beginning of the 24th week (final), heifers were bled for determinations of total serum protein, albumin and globulin; and plasma chloride, sodium and potassium. At the final bleeding analyses for haemoglobin and packed cell volume (P.C.V.) were also included. In addition, all calves were bled at this time and samples analysed for the same constitutents as those determined in the blood of their dams.

Daily observations were made on the general behaviour of the animals. Heifers calving during the daylight hours were observed. Animals showing manifest difficulty at calving were manually assisted and have been recorded as dystokias. Those retaining their placenta for longer than 72 hr were recorded and treated.

(iii) *Duration of the Experiment.*—The experimental treatment began on February 24, 1959, and continued for a period of 24 weeks. At this time the calves were weaned and kept in the yards for studies on early weaning. After determination of milk production the heifers were turned out to graze on *Paspalum dilatatum* pastures of adequate bulk but of poor quality.

IV. RESULTS

(i) *Silage Quality.*—In Table 1 the proximate analyses of a sample of silage without preparatory drying, a composite sample of silage resulting from bulking samples used for daily dry-matter determinations, and composite samples of silage fed and residues obtained from the three groups during the last 13 weeks are presented.

These analyses indicate that when the residues were not fed back the animals tended to select a ration lower in crude fibre and, in the case of Group I, higher in crude protein than that of the total feed presented. The higher protein (N x 6·25) in the residues for Groups II and III would suggest that all the urea was not being ingested.

The results of silage quality tests on the wet silage were as follows: dry-matter, 20·5 per cent.; pH, 3·6; lactic acid, 0·45 per cent.; and acetic acid, 0·57 per cent.

TABLE 1

PROXIMATE ANALYSES OF SAMPLES OF SORGHUM SILAGE AND RESIDUES

Sample	Moisture (%)	Crude Protein (%)	Ether Extract (%)	Crude Fibre (%)	Nitrogen-free Extract (%)	Ash (%)	Ca (%)	P (%)
Single*—As taken	79·5	0·9	0·5	7·0	10·7	1·4	0·07	0·01
D.M. basis†	..	4·3	2·2	34·1	52·4	7·0	0·35	0·05
Composite—D.M. basis	..	4·2	1·2	37·7	49·6	7·3	0·25	0·11
Composite‡ (July–August) (D.M.) ..	..	3·8	1·5	38·8	48·8	7·1	0·34	0·08
Residue—Group I (D.M.)	..	3·5	0·9	45·0	44·4	6·2	0·21	0·05
Residue—Group II (D.M.)	..	5·2	2·2	42·9	42·9	6·8	0·29	0·08
Residue—Group III (D.M.)	..	6·1	2·4	44·9	40·4	6·2	0·28	0·06

* Subsample from three sites in trench obtained prior to commencement of feeding.

† Corrected for loss of volatile material in drying.

‡ Composite (July-August) represents sample collected from silage fed during the period when residues were discarded after sampling.

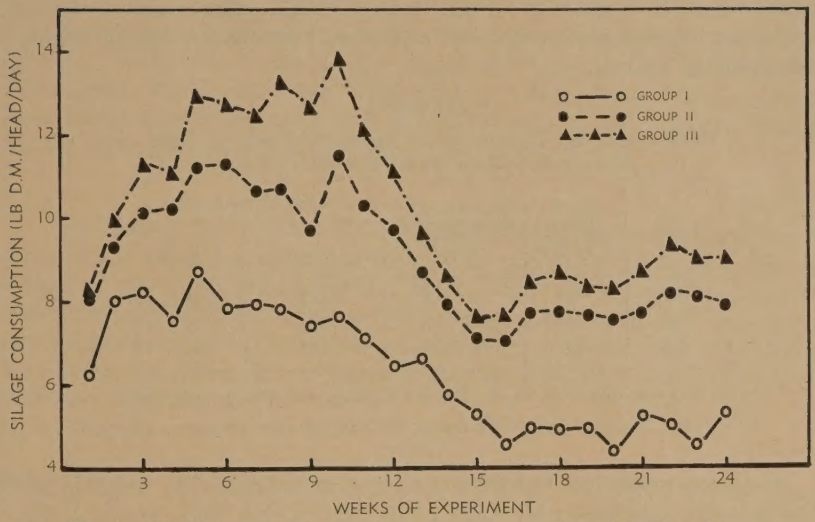

Fig. 1.—Weekly group mean sorghum silage consumption of heifers. Group I: Silage *ad lib.* Group II: Silage *ad lib.* + 1·5 oz. urea and 0·14 oz sodium sulphate per head per day. Group III: Silage *ad lib.* + 2·5 oz urea and 0·18 oz sodium sulphate per head per day.

The yellowish silage did not develop an unpleasant odour on exposure to air. Although there was only a moderate level of lactic acid, the appearance and low pH indicate a fair quality silage.

(ii) *Silage Consumption.*—The mean silage consumption per head per day on a dry-matter basis for each group calculated at weekly intervals is shown in Figure 1. Silage consumption in all groups showed a gradual decline from the 10th to the 16th week of feeding. Thereafter, the intake remained relatively constant in Group I, but increased slightly in Groups II and III.

The average daily dry-matter consumption for Groups I, II and III was 6·3, 9·0 and 10·2 lb per head respectively.

(iii) *Survival of Heifers.*—All heifers survived the silage feeding period, but two of the animals in Group I were weak and became prostrate within two weeks of being turned out to graze. One pregnant heifer was removed from Group I after 12 weeks of feeding because it showed symptoms resembling *otitis media.* Two heifers from Group II that had been in the experiment for 23 and 74 days aborted after 205 and 246 days' pregnancy respectively. The cause of the abortions could not be determined. Bacteriological examinations of both foetuses were negative for *Brucella abortus, Leptospira pomona, L. hyos, Vibrio fetus* and *Trichomonas foetus.*

(iv) *Body-weight of Heifers.*—The number of heifers calving at term, their mean initial body-weight, their body-weight loss prior to calving, and the mean period of silage feeding prior to calving are shown in Table 2. Group I lost significantly more weight than Groups II and III ($P < 0·001$) and Group II lost

significantly more weight than Group III ($P < 0{\cdot}05$). There were no significant correlations between body-weight loss and initial body-weight, date of calving or birth weight of the calf.

TABLE 2

MEAN PERIOD ON EXPERIMENT OF HEIFERS CALVING AT TERM AND MEAN BODY-WEIGHT CHANGES PRIOR TO CALVING

Group	No. of Heifers Calving at Term	Mean Period on Experiment Prior to Calving (days)	Mean Body-weight (lb)	
			Initial	Loss Prior to Calving
I	9*	107 ± 4	842	150 ± 10
II	8†	108 ± 5	818	79 ± 11
III	10	106 ± 4	845	42 ± 10

* One cow removed from Group I with symptoms resembling *otitis media.*

† Two cows from Group II aborted after 205 and 246 days' pregnancy respectively.

The mean weight loss in heifers at calving, as determined by weighing within 96 hr prior to parturition and within 24 hr after calving, were: Group I, 74 ± 8 lb; Group II, 84 ± 8 lb; and Group III, 102 ± 8 lb. Group III lost significantly more weight at calving than Groups I and II ($P < 0{\cdot}05$), while Group II lost significantly more weight than Group I ($P < 0{\cdot}05$). The weight loss at calving expressed as a percentage of weight before calving was 10·6, 11·1 and 12·6 per cent. for Groups I, II and III respectively. The birth weight of the calf accounted for 65·8, 60·1 and 54·7 per cent. of this weight loss in Groups I, II and III respectively. These differences were not significant.

The number of heifers lactating at the end of silage feeding, their mean body-weights at commencement of silage feeding, within 24 hr post-calving, and at the end of silage feeding, together with the mean body-weight loss during lactation and during the period of silage feeding, are shown in Table 3. The reduced number of heifers at this period in relation to the number of heifers calving at term is due to animals being removed from the experiment because they either had stillborn calves or because their calves had died.

TABLE 3

MEAN BODY-WEIGHT CHANGES OF HEIFERS LACTATING AT THE END OF SILAGE FEEDING

Group	No. of Lactating Heifers	Mean Stage of Lactation at Final Weighing (days)	Mean Body-weight (lb)				
			Initial	Post-calving*	Final	Loss During Lactation	Loss During Experimental Period
I	6	63 ± 2	865	634	480	154 ± 10	385 ± 17
II	7	64 ± 3	823	662	537	125 ± 10	286 ± 15
III	7	60 ± 4	850	716	614	102 ± 10	236 ± 15

* Body-weight post-calving was obtained within 24 hr after calving.

During lactation, Group I lost significantly more weight than Groups II and III ($P < 0{\cdot}01$) and Group II lost significantly more weight than Group III ($P < 0{\cdot}01$). During the whole silage feeding period, Group I lost significantly more weight than Group II ($P < 0{\cdot}01$) and Group III ($P < 0{\cdot}001$). Group II lost significantly more weight than Group III ($P < 0{\cdot}05$).

(v) *Calving Data.*—The mean gestation period, incidence of dystokia and retained placenta in the heifers calving at term, and the sex ratio and mean birth weights of the calves, are shown in Table 4. There was no significant difference between groups in gestation length. The overall incidence of both dystokia and retained placenta was 4 of 27 heifers calving at term, with no significant differences between groups. The cases of retained placenta were all in cows not requiring assistance at calving.

TABLE 4

GESTATION PERIOD AND INCIDENCE OF DYSTOKIA AND RETAINED PLACENTA IN THE HEIFERS, AND MEAN BIRTH WEIGHT AND SEX RATIO OF THE CALVES

Group	No. of Heifers Calving at Term	Gestation Period (days)	Mean Birth Weight of Calves (lb)	Sex Ratio Male : Female	Dystokia	Retained Placenta
I	9	280·0 ± 1·9	48·4 ± 2·3	5 : 4	1	3
I	8	283·1 ± 2·0	50·2 ± 2·4	4 : 4	1	1
III	10	282·4 ± 1·8	55·6 ± 2·2	4 : 6	2	0

The calves from Group III had significantly higher birth weights than those from Group I ($P < 0{\cdot}05$). Male calves in all groups were on the average 4·7 ± 2·7 lb heavier at birth than females but this difference was not significant.

(vi) *Mortality of Calves.*—The number of calves born at term, those stillborn and those dying during the period of silage feeding are shown in Table 5. The age of death of calves failing to survive is also shown.

TABLE 5

MORTALITY OF CALVES DURING EXPERIMENTAL PERIOD

Group	No. of Calves			Age at Death (days)
	Born at Term	Stillborn	Dying During Experimental Period	
I	9	0	4	7, 23, 54, 65
II	8	1	0	..
III	10	1	2	2*, 13

* This calf was destroyed due to deformity of the left forelimb.

The deaths of four calves in Group I were all considered to be due to the experimental treatment. Two of the calves died after creep feed was made available, one dying on the last day of the experiment. No milk was found in the abomasum of any of the calves at autopsy. Bacteriological examination of the internal organs and examination for internal parasites were negative in all cases. The one stillborn calf in each of Groups II and III was associated with a dystokia. No deaths occurred after birth in calves from Group II. In Group III, one live calf had a contracted flexor tendon in the left front leg and stood on the anterior aspect of the metacarpo-phalangeal joint. It was unable to move sufficiently to suckle and was destroyed at 2 days of age. The other calf that died in Group III was from a dam that required assistance at calving, had a birth weight of 48 lb and was weak at birth. It developed whitish, blood-stained scours at 6 days of age, gradually became weaker, and died at 13 days of age. The faeces was negative for *Salmonella* spp. and no common bacterial pathogens were found at autopsy.

(vii) *Growth Rate of Calves.*—The weight gains of calves surviving from birth to 7 days of age and of those surviving from birth to 28 days of age are shown in Table 6. These calves had access to their dams' milk and to the sorghum silage being fed to the heifers. There were no significant differences between groups at 7 days, but the difference between the means of Group I and II was significant ($P < 0{\cdot}05$) at 28 days.

TABLE 6

MEAN BODY-WEIGHT GAIN OF CALVES FROM BIRTH TO 7 DAYS AND BIRTH TO 28 DAYS

Group	Body-weight Gain (lb)	
	Birth to 7 days	Birth to 28 days*
I	2·7 ± 1·5	9·4 ± 2·8
II	6·9 ± 1·6	23·3 ± 2·8
III	3·9 ± 1·5	16·4 ± 2·8

* The regression coefficient of weight gain to 28 days on calving date was significant and means have been adjusted.

(viii) *Milk Production.*—For each group, the mean stage of lactation and the mean of the milk production for a 24-hr period at the completion of 24 weeks of silage feeding, together with standard errors, are shown below:

Group	Mean Stage of Lactation (days)	Mean Milk Production (ml)
I	63 ± 2	485 ± 169
II	64 ± 3	1251 ± 157
III	60 ± 4	1062 ± 157

Groups II and III produced significantly more milk ($P < 0{\cdot}05$) than Group I. There was no significant correlation between milk production and either date of calving or birth weight of the calf.

TABLE 7

GROUP MEANS FOR BLOOD AND SERUM ANALYSES OF CATTLE FED SORGHUM SILAGE AND SORGHUM SILAGE PLUS TWO LEVELS OF UREA

Determination	Group I		Group II		Group III	
	Initial	Final	Initial	Final	Initial	Final
Total serum protein (g/100 ml) ..	7·8	6·9 ± 0·3*	7·9	6·5 ± 0·3**	8·1	6·9 ± 0·3**
Serum albumin (g/100 ml)	3·7	3·2 ± 0·1*	3·7	3·3 ± 0·1	3·8	3·5 ± 0·1
Serum globulin (g/100 ml)	4·1	3·7 ± 0·4	4·2	3·1 ± 0·3*	4·3	3·4 ± 0·3*
Plasma chloride (m-equiv./l)	108·2	106·2 ± 0·8	112·9	104·1 ± 0·7***	110·5	104·1 ± 0·7**
Plasma sodium (m-equiv./l)	141·6	135·1 ± 1·6**	142·5	136·5 ± 1·5**	144·9	136·9 ± 1·5**
Plasma potassium (m-equiv./l) ..	4·8	4·8 ± 0·3	4·8	4·3 ± 0·3	5·5	5·0 ± 0·3
Blood haemoglobin (g/100 ml) ..	..	11·2 ± 0·7	..	11·6 ± 0·6	..	13·1 ± 0·6
P.C.V. (%)	..	33·3 ± 2·2	..	35·2 ± 2·1	..	38·9 ± 2·1

*, **, ***—Final value significantly higher (or lower) than initial value at 5%, 1% and 0·1% levels respectively.

(ix) *Biochemical Values.*—The initial and final values for serum total protein, albumin and globulin; and plasma chloride, sodium and potassium on samples obtained from the heifers are shown in Table 7. Final values for haemoglobin and P.C.V. are also included in Table 7. There were no significant differences among group final means. Final values for serum total protein and plasma sodium showed a significant decline from initial values in all groups. There was a similar result for plasma chloride in Groups II and III.

The values for serum total protein, albumin and globulin; plasma chloride, sodium and potassium; haemoglobin and P.C.V. on blood samples obtained from the calves during the last week of silage feeding are shown in Table 8. Calves from heifers in Group II showed significantly higher mean haemoglobin ($P < 0{\cdot}05$) and P.C.V. ($P < 0{\cdot}01$) levels than calves from Groups I and III. The mean plasma sodium level for Group III calves was significantly higher than those for calves from Groups I and II. No other differences were significant.

TABLE 8

GROUP MEANS AND STANDARD ERROR FOR BLOOD AND SERUM ANALYSES OF CALVES FROM HEIFERS FED SORGHUM SILAGE AND SORGHUM SILAGE PLUS TWO LEVELS OF UREA

Determination	Group I	Group II	Group III
Total serum protein (g/100 ml) ..	5·7 ± 0·2	6·2 ± 0·2	5·9 ± 0·2
Serum albumin (g/100 ml) ..	3·5 ± 0·1	3·6 ± 0·1	3·4 ± 0·1
Serum globulin (g/100 ml) ..	2·2 ± 0·2	2·6 ± 0·2	2·5 ± 0·2
Plasma chloride (m-equiv./l) ..	105·5 ± 1·1	103·1 ± 1·0	102·5 ± 1·0
Plasma sodium (m-equiv./l) ..	134·6 ± 1·2	134·6 ± 1·1	139·4 ± 1·1
Plasma potassium (m-equiv./l) ..	5·1 ± 0·2	5·3 ± 0·2	5·4 ± 0·2
Blood haemoglobin (g/100 ml) ..	12·0 ± 0·5	13·5 ± 0·4	11·8 ± 0·4
P.C.V. (%)	37·7 ± 1·5	46·5 ± 1·4	37·0 ± 1·4

V. DISCUSSION

This experiment was designed to evaluate sorghum silage as a survival fodder for cattle during late pregnancy and early lactation. The silage was comparable in chemical composition with the product made from sorghum grown in the low-rainfall areas of western Queensland.

The experiment was conducted in bare yards under simulated drought feeding conditions. Animals were fed for 24 weeks, commencing 106-108 days (group means) prior to calving and terminating 60-64 days (group means) after calving.

The findings indicated that silage of the quality used, when fed as the sole ration, resulted in marked weight losses in heifers prior to calving and low birth weights and poor survival of calves. Some of the heifers were very weak at the conclusion of feeding. The supplementation of the silage with non-protein nitrogen in the form of urea, at levels of 1·5 oz and 2·5 oz per head per day, resulted in increased silage consumption, reduced weight losses in the heifers and markedly lower calf mortality.

The daily addition of 1·5 oz and 2·5 oz urea per head increased the consumption of silage by 43 and 62 per cent. respectively. This is in agreement with the findings of Morris (1958*b*) for maiden heifers fed sorghum silage and supplemented with the same amounts of urea.

The gradual decline in silage consumption in all groups from the 10th to the 16th week could be due to a number of factors. Firstly, it could be associated with the loss in body-weight of the animals. Morris (1958*b*) recorded a gradual increase in intake of silage in the groups of maiden heifers showing a gain in body-weight and a gradually decreasing intake in the group declining in body-weight. Secondly, the quality and palatability of the silage could have varied with the location in the trench. The lower crude protein content of the composite sample obtained during the last 13 weeks when compared with that collected during the whole experimental period would indicate that the chemical composition was variable. As a response in intake was obtained with the addition of nitrogen to this silage, it could be expected that any decrease in the crude protein content of the basal silage would result in a reduced intake. Thirdly, it has been postulated by Mäkelä (1956), cited by Blaxter (1957), that the space occupied by the developing foetus in the abdominal cavity could be a factor in reducing intake of bulky feeds. Some support for this hypothesis is evident because the major decline commenced approximately 3 weeks before the first cow calved and continued until the groups contained a number of lactating animals. Intake increased slightly after most of the heifers had calved. However, all intakes were low and this, together with the fact that the group on the lower intake also declined but at a slightly slower rate, would suggest that this was not the only factor operating.

The supplement of urea resulted in a significantly reduced weight loss in the heifers. However, at the levels fed, it did not permit the maintenance of body-weight in the pregnant heifers, despite the increasing contribution of the foetus, foetal membranes and fluids to the recorded weight.

Nutritive requirements increase in the last third of pregnancy, since approximately two-thirds of the foetal growth occurs during this period (Winters, Green, and Comstock 1942). If nutrition plays a part in the birth weight of calves, then the plane of nutrition in the later stages of pregnancy is likely to be the more important. In this experiment the mean weight losses in heifers in the last 106-108 days of pregnancy (group means) were 1·4 lb per head per day for the group receiving silage alone and 0·7 lb and 0·4 lb per head per day for the groups receiving in addition a daily supplement of 1·5 oz and 2·5 oz of urea per head respectively. The mean birth weight of the calves from the unsupplemented group was significantly lower than that of calves from the group receiving the higher level of urea supplementation. This is in agreement with the findings of Wallace (1948) for sheep. It is also in agreement with the conclusion made by Blaxter (1957), on the basis of published work, that birth weight in cattle reflects maternal nutrition. Joubert and Bonsma (1957), comparing "high" and "low" planes of nutrition, in which heifers showed weight changes of + 173·8 lb and — 28·2 lb respectively from conception to weight pre-partum, obtained no significant differences in birth

weights of calves. They concluded that it was possible for a heifer to produce a calf of normal weight at birth without her gaining any weight at all during pregnancy provided she had reached 70-80 per cent. of her ultimate mature weight prior to pregnancy. In the experiment reported in the present paper, all groups actually showed a gain between mating and pre-partum weight, but this represented a mean gain of approximately 1 lb per head per day in the first 6 months of pregnancy and a variable weight loss in the last third of pregnancy. The actual stage when nutritional stress occurs and its severity are likely to be important factors in determining birth weight of calves.

Under the conditions of this experiment, it was not possible to assess accurately the weight loss of heifers at calving. The data obtained by the method used, viz. weighing the dam within 96 hr prior to calving and within 24 hr after calving, are in agreement with the findings of Eckles and Swett (1918) and Joubert and Bonsma (1957), who found a lower weight loss at calving in "low" plane heifers compared with "high" plane heifers.

In simulated drought feeding experiments of this nature, where the energy expenditure of the heifers in obtaining feed was minimized by confinement in yards, it would appear on the limited data available that the calf would die from malnutrition before the dam succumbed. Reliable field data for grazing cows and their calves during drought are not available.

The milk production, as assessed by milk obtained over a period of 24 hr at group mean lactation periods of 60–64 days, was significantly higher in the two groups receiving urea. This was reflected in the higher mean weight gains during the first 28 days of the calves suckling heifers in the two supplemented groups. However, the weight advantage was significant only in the group receiving the lower level of urea.

The milk production of the cows and the growth rate of calves from the group receiving the lower level of urea were higher, but not significantly different from those receiving the higher level of urea. It is possible that the potentially higher milk producers were allotted to the former group when they were randomized on the basis of mating date.

The method used for the assessment of milk production must be regarded only as comparative. There is evidence (J. W. Ryley and R. J. W. Gartner, to be published) that even with milk yields of this order, the amount obtained after a 24-hr milking interval is much less than the 24-hr yield calculated from a 4-hr milking interval. Also, the amount actually obtained by the calf may vary from that obtained by hand-milking.

Morris (1958*b*) reported that maiden heifers fed sorghum silage supplemented with 1·5 oz or 2·5 oz of urea per head per day for 28 weeks had significantly higher total plasma protein concentrations than those fed sorghum silage alone. In this experiment with lactating animals, there was no significant difference in serum protein concentration between groups at the conclusion of the feeding, although all groups showed values significantly lower than initial levels.

These values for the group receiving silage alone were higher than those obtained by Morris (1958*b*). Only one animal from the group fed solely on sorghum silage showed any visible evidence of oedema of the submaxillary space, whereas a high incidence was recorded by Morris (1958*b*) in the comparably fed group of maiden heifers.

Although final values were significantly lower than initial levels for plasma sodium in all groups and for plasma chloride in the two groups receiving urea, the final levels could not be regarded as pathological. The biochemical values on blood and serum from the calves are comparable with those obtained in Hereford calves, of similar age, suckling dams grazing the predominantly *Paspalum dilatatum* pastures at the Animal Husbandry Research Farm, Rocklea (unpublished data). The higher haemoglobin concentration and P.C.V. in the calves suckling animals receiving a supplement of 1·5 oz urea per head per day are consistent with the better growth shown by these calves.

The results of this experiment were obtained with heifers initially in forward condition and gaining approximately 1 lb per head per day during the first two-thirds of pregnancy. Graziers would be unlikely to contemplate feeding for survival until cattle were in much poorer condition. It is therefore evident that sorghum silage stored with a view to feeding pregnant or lactating cattle during drought should be either of better food value than that used in this experiment or be fed with supplements. From this experiment it is evident that such supplements should be high in nitrogen. The provision of a sorghum silage of higher protein content would necessitate either conservation at a younger stage of growth, or the conservation of mixtures of sorghum and a leguminous plant.

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BAGOMOLASSES AS THE BASIS OF A FATTENING RATION FOR CATTLE

By R. M. Beames, B. Agr. Sc. *

SUMMARY

Three groups of five steers 21-27 months of age were fed individually for 17 weeks on rations containing up to 70 per cent. bagomolasses.

The bagomolasses, which contained 70 per cent. molasses and 30 per cent. bagasse, was combined in various proportions with meatmeal, urea, sorghum meal, lucerne chaff and salt. The ration for Group I contained 70 per cent. bagomolasses and 2.16 per cent. nitrogen. Group II received a similar level of bagomolasses but 1.5 per cent. nitrogen. The ration for Group III contained 2.11 per cent. nitrogen. Grain was incorporated in this ration to reduce the level of bagomolasses to 50 per cent.

A comparable group of five animals was slaughtered for carcass appraisal at the commencement of the experiment. The remainder were slaughtered at the conclusion of the 17 weeks' feeding. Response to the rations was measured by body-weight gains and changes in carcass weight and composition. The digestibility of bagomolasses was determined.

The mean daily air-dry feed intake in Group III of 22.4 lb per head per day was significantly higher ($P<0.05$) than that in either Group I or Group II (18.0 and 16.9 lb respectively). Mean respective body-weight gains for Groups I, II and III were 1.4, 1.5 and 2.3 lb per day on a non-shrunk basis and 1.1, 1.0 and 1.7 lb per day on a shrunk basis. Carcass weights in Group III were correspondingly higher than in the other two groups, over 66 per cent. of this difference being due to fat deposition.

Bagomolasses was shown to have an apparent dry-matter digestibility of approximately 52 per cent. Apparent digestibility of crude protein was 16.7 per cent. and crude fibre 21.3 per cent.

From these results it is considered that bagomolasses should not comprise more than 50 per cent. of a cattle fattening ration.

I. INTRODUCTION

In Queensland, from an annual production of approximately 9 million tons of sugar cane, over 220,000 tons of molasses are produced (Nicklin and Brain 1960). Although production of molasses has approximately doubled since 1947, the amount of molasses used as stock feed has not increased, the extra production being used in distilleries or as fertilizer. Another by-product, bagasse, is used mostly as a fuel for mills. A small amount is used in the production of an insulating material, but 190,000 tons, or approximately 10 per cent. of the total production, is not used commercially. Possible uses of this surplus are in the production of paper and hardboard (Nicklin 1957; Nicklin and Brain 1959) and as a carrier for molasses in stock feeds (Wood 1934).

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Much work has been done on the feeding value of molasses but very little on the utilization of bagasse-molasses mixtures (bagomolasses). Some of the more important results have come from the United States of America (Lamb 1938; Bray, Snell, Morrison, and Jackson 1945; Lathrop, Aronovsky, and Naffziger 1951; Anon. 1951; Wayman, Iwanaga, Morita, and Henke 1952), India (Ray and Talapatra 1945; Ayyar and Zubery 1945) and Trinidad and British Guiana (Scott 1950). Bagasse contains 40-50 per cent. fibre, 18-20 per cent. lignin and no digestible protein. Kamstra, Moxon, and Bentley (1958) have shown that lignin itself is virtually indigestible and by a process of encrustation can also reduce the digestibility of cellulose by 50-75 per cent. Because of the high fibre and lignin content of bagasse, the T.D.N. value of 46·5 (Morrison 1959) would tend to over-estimate its feeding value.

Freight costs are of major importance in the inland areas of Queensland. From this aspect alone, bagasse, being of low feeding value, would be uneconomical as a drought fodder when compared with grains. In this State, the best use of bagomolasses would be as the roughage portion of a topping-off ration for cattle fed in close proximity to the sugar mills.

This paper gives the results of a feeding experiment with cattle using rations containing high levels of bagomolasses. The concentrates used in the rations were selected on the basis of the cost and availability in Queensland. Bagomolasses containing 70 per cent. molasses and 30 per cent. bagasse was chosen, as this is the highest concentration of molasses which would permit transportation in jute bags. The digestibility of the bagomolasses was also determined.

II. MATERIALS AND METHODS

(i) *Animals.*—The cattle used in the feeding experiment were Hereford steers 21-27 months of age, in store condition. They were bred and reared in south-eastern Queensland. Three mature dairy-type steers were used for the determination of the digestibility of bagomolasses.

(ii) *Housing.*—The animals were housed in individual stalls with concrete flooring and troughing. Softwood shavings were supplied as bedding. Water was available *ad lib.* from automatic drinkers.

(iii) *Rations.*—The following rations were used:

	I	II	III
	%	%	%
Bagomolasses	70	70	50
Meat-and-bone meal	10	8	5
Urea	1	..	1
Sorghum meal	12	15	37
Lucerne chaff	5	5	5
Sodium chloride (coarse)	2	2	2

The bagomolasses was 70 per cent. molasses and 30 per cent. bagasse by weight and was prepared in a screw mixer. The urea was fertilizer grade (45·4 per cent. nitrogen on air-dry basis). The lucerne chaff, sorghum meal and meat-and-bone meal were uniform lines obtained prior to commencement of the experiment.

(iv) *Sampling and Analysis.*—Samples of ration components were taken prior to the experiment except in the case of bagomolasses, where each bag was sampled as used and the pooled sample analysed.

All analyses of feed, faeces and carcass were done by the official A.O.A.C. methods (Association of Official Agricultural Chemists 1955).

Carcass composition was estimated from analysis of the 9th, 10th and 11th rib cut, using the regressions of Hankins and Howe (1946) given below:

$$Y_1 = 2{\cdot}82 + 0{\cdot}77\,X_1 \quad .. \quad .. \quad .. \quad .. \quad (1)$$
$$Y_2 = 5{\cdot}98 + 0{\cdot}66\,X_2 \quad .. \quad .. \quad .. \quad .. \quad (2)$$
$$Y_3 = 14{\cdot}90 + 0{\cdot}78\,X_3 \quad .. \quad .. \quad .. \quad .. \quad (3)$$
$$Y_4 = 4{\cdot}30 + 0{\cdot}61\,X_4$$

Y_1 = percentage ether extract in the edible portion* of the carcass ;
X_1 = percentage ether extract in the edible portion* of the rib cut ;
Y_2 = percentage protein in the edible portion* of the carcass ;
X_2 = percentage protein in the edible portion* of the rib cut.
Y_3 = percentage water in the edible portion* of the carcass ;
X_3 = percentage water in the edible portion* of the rib cut ;
Y_4 = percentage separable bone in the whole of the carcass ;
X_4 = percentage separable bone in the whole of the rib cut.

* Edible portion refers to the whole less the bone.

To correct equations (1), (2) and (3) to percentages in the whole carcass, the following formulae were used:

$$\text{Ether extract} = \frac{0{\cdot}99\,Y_1\,(100-Y_4)}{Y_1 + Y_2 + Y_3}$$

$$\text{Protein} = \frac{0{\cdot}99\,Y_2\,(100-Y_4)}{Y_1 + Y_2 + Y_3}$$

$$\text{Water} = \frac{0{\cdot}99\,Y_3\,(100-Y_4)}{Y_1 + Y_2 + Y_3}$$

The factor 0·99 is a correction for an allowance of 1 per cent. ash in the edible portion of the carcass.

(v) *Digestibility.*—In the digestibility trial, faeces were collected by using harness to the design by Ballinger and Dunlop (1946). Animals were individually housed in stalls. No bedding was used. The precollection period was 10 days and the collection period 7 days.

The digestibility of bagomolasses was determined by difference. In the first period each animal was fed slightly below its maximum intake on a ration of 50 per cent. lucerne chaff, 50 per cent. bagomolasses, mixed on an air-dry basis. In the second period each animal was fed lucerne chaff of air-dry weight similar to the total air-dry weight in the first period.

(vi) *Body-weight.*—Initial and final body-weights were obtained on a shrunk (18 hr without feed and water) basis. Non-shrunk body-weights were obtained at fortnighly intervals. All weighings were made on scales with an accuracy of ± 1 lb at 8.30 a.m. before the morning addition of feed.

III. EXPERIMENTAL

Twenty steers were allotted by stratified random sampling on the basis of body-weight into four groups of five and placed on the following treatments:

Groups I, II and III were assigned to Rations I, II and III respectively. Group IV was slaughtered at the commencement of the experiment.

The rations were fed *ad lib.* The duration of the feeding period was 17 weeks, this being determined by the time taken for the most rapidly gaining group to reach a degree of finish which was considered suitable for the local trade.

On being stalled, the animals were fed lucerne chaff; this was progressively changed to the experimental ration over the first 2 weeks of the 17-week feeding period.

Feed was before the animals at all times and was added to twice daily. Residues were weighed daily and fed back.

Carcasses of Group IV at the commencement of the experiment and of Groups I, II and III at the conclusion were sampled for analysis to estimate the separable bone, protein, water and ether extract.

IV. RESULTS

(i) *Feed Analyses.*—Proximate analyses of the ration components are given in Table 1. The composition, estimated starch equivalent and digestible protein percentage of the rations are shown in Table 2.

TABLE 1

PROXIMATE ANALYSES OF RATION COMPONENTS IN FATTENING EXPERIMENT

Component	Moisture (%)	Crude Protein (%)	Ether Extract (%)	Crude Fibre (%)	Nitrogen-free Extract (%)	Ash (%)	Ca (%)	P (%)
Bagomolasses 70/30	16·5	3·9	0·2	13·0	55·5	11·0	1·04	0·11
	..	*4·7*	*0·26*	*15·6*	*66·2*	*13·2*	*1·24*	*0·15*
Meat-and-bone meal	7·6	58·1	4·5	..	9·0	20·8	6·8	3·26
	..	*62·9*	*4·9*	..	*9·7*	*22·5*	*7·4*	*3·52*
Sorghum meal ..	13·5	10·6	2·7	2·3	69·4	1·5	0·03	0·30
	..	*12·2*	*3·1*	*2·6*	*80·4*	*1·7*	*0·03*	*0·34*
Lucerne chaff ..	13·2	16·9	1·2	20·5	41·6	6·6	0·79	0·28
	..	*19·4*	*1·3*	*23·6*	*48·1*	*7·6*	*0·86*	*0·32*

Italics indicate composition on a dry-matter basis.

TABLE 2

CHEMICAL COMPOSITION, ESTIMATED STARCH EQUIVALENT AND DIGESTIBLE PROTEIN OF RATIONS I, II AND III

	Moisture (%)	Crude Protein* (%)	Ether Extract (%)	Crude Fibre (%)	Nitrogen-free Extract (%)	Ash (%)	Ca (%)	P (%)	Digestible Crude Protein† (%)	Starch Equivalent ‡ (%)
Ration I	14·6	13·5	1·0	10·4	49·8	12·3	1·4	0·5	9·3	39
	..	*15·8*	*1·2*	*12·2*	*58·4*	*14·4*	*1·6*	*0·6*	..	..
Ration II	14·7	9·8	1·0	10·5	51·7	11·9	1·3	0·4	6·1	40
	..	*11·4*	*1·2*	*12·3*	*60·5*	*13·9*	*1·5*	*0·5*	..	..
Ration III	14·2	13·2	1·4	8·4	55·8	9·4	0·9	0·3	8·9	49
	..	*15·4*	*1·6*	*9·8*	*65·0*	*10·9*	*1·0*	*0·4*	..	..

Italics indicate composition on a dry-matter basis.

* (N x 6·25).

† Digestible protein percentage of bagomolasses taken from Table 5. Urea nitrogen is given a digestibility of 90 per cent. (Beames 1959). Values for other ration components taken from Morrison (1959).

‡ Starch equivalent by method described by Woodman (1957).

(ii) *Feed Consumption.*—The means of the total and daily air-dry feed consumptions over the whole experimental period are given in Table 3. The progressive mean daily consumptions calculated at weekly intervals are shown in Figure 1. In all groups, and particularly in Group I, intakes fluctuated but showed a general increase as the experiment progressed. At all times the consumption in Group III was greater than that in either Group I or Group II. The initial intakes in all groups were low, with Group III being the only one to achieve a satisfactory level for most of the experiment. The mean daily intake of 22·4 lb in Group III was significantly ($P < 0{\cdot}05$) higher than those in Groups I and II, which were 18·0 lb and 16·9 lb respectively. There was no significant difference between feed intakes of Groups I and II.

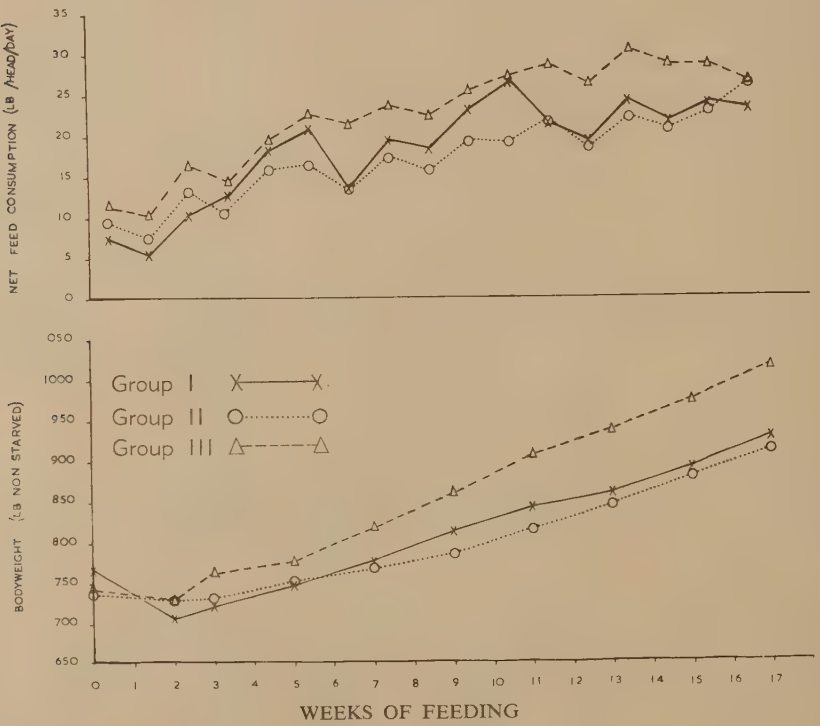

Fig. 1.—Net feed consumptions and bodyweight changes of Groups I, II and III over the 17-week feeding period.

(iii) *Body-weight.*—Initial and final body-weights are given in Table 3, with fortnightly changes shown in Figure 1. On the non-shrunk basis, Group III performed significantly ($P < 0{\cdot}01$) better than Groups I and II, between which there was no significant difference. On the shrunk basis, Group III made greater weight gains than Group II ($P < 0{\cdot}01$) and Group I ($P < 0{\cdot}05$). The weight

increases in all groups on a shrunk basis were much smaller than on a non-shrunk basis, being 0·3–0·6 lb per day less. Dressing percentages on a shrunk basis were correspondingly higher, being 1·8 per cent. units in the group slaughtered initially and 3·8–4·5 per cent. units in the groups slaughtered at the conclusion.

TABLE 3

Body-weight Changes and Feed Consumption over the 17-week Experimental Period

—	Group I	Group II	Group III	Group IV	Necessary Difference	
					P < 0·05	P < 0·01
Non-shrunk body-weight (lb)—						
Initial	763	738	745	751	..	..
Final	926	912	1,012	..	..	..
Total gain	163	174	267	..	65	91
Mean gain/day	1·4	1·5	2·3	..	0·55	0·77
Shrunk body-weight (lb)—						
Initial	733	722	728	726	..	..
Final	862	843	930	..	..	..
Total gain	129	121	202	..	54	76
Mean gain/day	1·1	1·0	1·7	..	0·45	0·63
Dressing percentage*—						
(*a*) Non-shrunk basis ..	52·3	53·6	55·1	49·3	..	..
(*b*) Shrunk basis	56·1	58·1	59·4	51·1	..	..
Difference (b—a)	3·8	4·5	4·3	1·8	..	..
Air-dry feed consumption (lb)—						
Total	2,120	1,996	2,638	..	490	686
Mean/day	18·0	16·9	22·4	..	4·1	5·7

* Based on hot dressed weight.

(iv) *Carcass Analysis.*—The carcass analyses of Group IV slaughtered at the commencement of the feeding period and Groups I, II and III slaughtered at the conclusion of the feeding period are given in Table 4. In all these analyses Group III was markedly different from Groups I and II, which, on the whole, had comparable performance throughout. In the whole carcass, Group III had a greater percentage of ether extract than Groups I and II ($P < 0·01$) and a lower percentage of carcass water than either Groups I ($P < 0·05$) or II ($P < 0·01$). Each group made an average increase of 16·1–18·9 lb in skeletal growth (i.e. separable bone), with no significant difference between groups.

(v) *Carcass Quality.*—In the commercial assessment of carcass quality of Groups I, II and III by visual appraisal, all carcasses were classed as 1st quality, except one in Group I, which was classed as 2nd quality. Of the group slaughtered at the commencement of the trial, four were classed as 2nd quality and one as 3rd quality.

(vi) *Digestibility.*—Results of the digestibility trial are given in Table 5. Apparent digestibility of both crude protein (16·7 per cent.) and crude fibre (21·3 per cent.) was low, while that of nitrogen-free extract was comparatively high (65·1 per cent.).

TABLE 4

PERCENTAGE AND TOTAL WEIGHTS OF CARCASS COMPONENTS AT SLAUGHTER, CALCULATED FROM PERCENTAGES IN THE 9TH, 10TH AND 11TH RIB CUT

Carcass Component	Group Means				Necessary Difference	
	I	II	III	IV	$P < 0.05$	$P < 0.01$
Percentage in separable portion—						
Ether extract	20·3	20·0	27·2	13·7	4·4	6·2
Protein	17·0	16·4	15·7	18·0	1·1	1·6
Water	61·4	61·5	55·8	64·4	3·3	4·7
Total	98·5	97·9	98·8	96·1	1·0	1·5
Percentage in whole carcass—						
Ether extract	16·9	17·1	23·2	11·8	3·9	5·5
Protein	14·2	14·0	13·5	15·3	1·0	1·4
Water	51·5	52·2	47·7	55·1	3·2	4·4
Separable bone	16·5	16·1	14·7	17·0	1·2	1·7
Weight in whole carcass (lb)—						
Total	484	490	557	370	32	44
Ether extract	81·8	83·8	129·2	43·6	24·5	34·3
Protein	68·7	68·6	75·2	56·6	4·1	5·7
Water	249·3	255·8	265·7	203·9	12·8	17·9
Separable bone	79·7	78·8	81·6	62·7	7·1	9·9

TABLE 5

APPARENT DIGESTIBILITY OF BAGOMOLASSES DETERMINED BY DIFFERENCE

Animal No.	Mean Body-weight (lb)	Average Dry-matter Intake/Day (lb)		Digestibility (%)			
		Period 1	Period 2	Dry Matter	Crude Protein	Fibre	Nitrogen-free Extract
36	718	12·4	13·5	51·2	7·0	21·4	64·9
37	700	12·5	13·5	50·0	20·4	18·6	65·1
38	1,418	16·7	18·0	53·9	22·8	24·0	65·3
Mean	..	..	..	51·7	16·7	21·3	65·1

V. DISCUSSION

The high bagomolasses content of Rations I and II resulted in a low estimated starch equivalent (approximately 40 per cent. for each ration). It was anticipated that on these two rations a high feed intake would partly compensate for the low energy level. However, only towards the conclusion of the experiment were the intakes of these two rations considered satisfactory. The main difference between Ration I and Ration II was in the level of nitrogen (Table 2), this difference being provided mainly in the form of urea. For there to be no difference between the results achieved by these rations one would assume that some factor

other than nitrogen was limiting in both rations, or that urea was ineffective in a production ration. This latter explanation would tend to be discounted by the findings of several workers using sheep (Harris and Mitchell 1941; Johnson, Hamilton, Mitchell, and Robinson 1942; Hamilton, Robinson, and Johnson 1948). These findings should apply to cattle, as they have been reported to respond as well as, if not better than, sheep to urea feeding (Gallup, Pope, and Whitehair 1953; Morris 1958). Dinning, Briggs, and Gallup (1949) showed urea to be well utilized in a fattening ration for both cattle and sheep when it provided approximately 20 per cent. of the total nitrogen intake.

The body-weight changes in Group III could be considered satisfactory for fattening cattle, i.e. 2·3 lb per day on a non-shrunk basis and 1·7 lb per day on a shrunk basis. The marked difference between the data calculated on a shrunk and non-shrunk basis emphasizes the importance of standardizing the weighing technique as shown by Hughes and Harker (1950) and Taylor (1954).

An important factor in the rate of gain in all groups was the length of time taken for feed intakes to rise to a somewhat steady level (Figure 1). Over the final 10 weeks of the 17-week period the mean daily weight increases (on a non-shrunk basis) of 2·1, 2·1 and 2·9 lb for Groups I, II and III respectively, as compared with those over the total period of 1·4, 1·5 and 2·3 lb respectively, are perhaps a better measure of the capabilities of the rations.

The quantitative type of carcass analysis of Hankins and Howe (1946) was used in this experiment in preference to the system of either McMeekan and Walker (1950) or Yeates (1952), in which no statistical analyses can be made on the results, and to the more exact but more time-consuming dissection techniques of Callow (1947) and Watson, Kennedy, Davidson, Robinson, and Muir (1949). Hopper (1944) found that the analysis of the 9th, 10th and 11th rib cut had a high degree of correlation ($r = 0{\cdot}95$) with total carcass analysis, although his regressions differed from those of Hankins and Howe (1946). More recently, Kraybill, Bitter, and Hankins (1952) showed that the specific gravity of the 9th, 10th, 11th rib cut was highly correlated ($r = 0{\cdot}95$) with that of the whole carcass.

The equal amount of bone growth in all groups (Table 3) is understandable, as the mean calcium and phosphorus intake in each was above the National Research Council (1958) requirements for fattening yearling cattle. The low energy value of the rations and low feed intakes in both Group I and Group II could explain the low fat and protein deposition in these groups. When these carcass analysis figures are compared with those calculated by Callow (1950) for young steers, it is seen that the weight of bone in Group III and Group IV was comparable with Callow's figures but was high in Groups I and II. Weight of protein was higher than Callow's figures in all groups, whereas ether extract (fat) was similar in Group III, less in Groups I and II and much less in Group IV. Thus, taking the data of Callow as being representative of normal well-grown young steers, the steers used in this experiment at the commencement of feeding had made

normal skeletal and muscular growth. On the experimental rations, normal growth continued, but only in Group III was the deposition of fat brought to an adequate level.

The high apparent digestibility of nitrogen-free extract of bagomolasses could be explained by the high molasses content. The variability in apparent digestibility of the crude protein of bagomolasses could have been caused by small variations in the percentage of metabolic faecal nitrogen, especially in a determination such as this where the method of difference was used on a low-nitrogen feedstuff. The low average apparent digestibility of fibre (21·3 per cent.) of bagomolasses could have been a result of the high lignin content of bagomolasses, aggravated by a high carbohydrate level in the feed (Hoflund, Quin, and Clark 1948).

Essentially, the findings from these data are that a ration containing 50 per cent. bagomolasses is suitable for topping-off beef cattle, whereas a ration containing 70 per cent. bagomolasses appears to be limiting in energy.

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RELATIONSHIPS AMONG PRODUCTIVE CHARACTERS OF MERINO SHEEP IN NORTH-WESTERN QUEENSLAND

1. ESTIMATES OF PHENOTYPIC PARAMETERS

By A. W. Beattie, B.Sc.Agr. *

SUMMARY

Estimates of repeatability and phenotypic relationships among 10 fleece characters were obtained from a flock of Merino sheep at the Toorak Field Station, Julia Creek. The repeatability of all characters was high, ranging from 0.45 to 0.80.

Phenotypic correlations were generally comparable with published data for similar strains. The principal antagonistic relationship is that between clean wool weight and crimp frequency ($r = -0.45$).

I. INTRODUCTION

A knowledge of the phenotypic relationships among characters of economic importance makes it possible to predict the effect of culling operations on the subsequent performance of the retained portion of the flock. The phenotypic statistics are also required in predicting the genetic consequences of selection when selection is based on more than one character.

Estimates of means, standard deviations, repeatabilities and phenotypic correlations were reported by Morley (1951, 1955) for eight sheep and wool characters measured in the flock of Trangie Agricultural Experiment Station in New South Wales. Young, Turner, and Dolling (1960) presented estimates of repeatability obtained from "Gilruth Plains" Field Station in south-western Queensland. They paid particular attention to the possibility of sex differences, but concluded that at least with respect to the 10 characters considered by them, estimates obtained from ewes were equally applicable to rams.

The aim of this study was to obtain estimates of phenotypic parameters from sheep run in a third type of environment, that of north-western Queensland.

II. MATERIALS AND METHODS

(i) *Environment.*—Toorak Field Station is situated 35 miles south of Julia Creek, Queensland. It comprises 36,000 ac of open Mitchell grass downs country and is typical of much of the north-western pastoral zone of the State. Mitchell grasses (species of *Astrebla*) dominate the perennial pasture. The annual Flinders grasses (species of *Iseilema*) and button grass (*Dactyloctenium radulans*) make a significant contribution in some seasons.

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The rainfall averages under 17 in. and is strongly seasonal. Very little rain falls during the winter months and about half the annual total is typically recorded in January and February. Periodic droughts occur when the summer rains fail. Monthly average maximum screen temperatures exceed 95°F for 4–6 months each summer. Daily maxima commonly exceed 100°F consecutively for periods of 2–3 weeks. In the coldest months of the year, June and July, maxima in the high 70's occur. Winter minima average about 45°F, but may be much lower during periods of strong westerly to south-westerly winds.

(ii) *Sheep.*—The data were obtained from a flock of Merino ewes of Medium Peppin origin locally bred and introduced to the Field Station as yearlings in 1951. Drought conditions delayed their first mating until 1953, since when they have been mated annually in the autumn. Results from the ewe progeny of these foundation animals have also been included.

These sheep are used primarily for investigations into life-time productivity and fertility. Therefore, no culling of ewes has been practised at any time.

(iii) *Characters Measured.*—The characters studied were:

Greasy Wool Weight.—Total fleece weight including bellies but excluding skirtings and locks.

Per cent. Clean Scoured Yield.—The percentage of bone-dry clean wool (free of vegetable matter and scouring residuals) in a midside sample of the fleece.

Clean Wool Weight.—Calculated as the product of greasy wool weight and clean scoured yield.

Fibre Diameter.—The mean diameter of 100 fibre snippets from a subsample of the scouring sample.

Coefficient of Variation of Fibre Diameter.—Calculated from the individual fibre diameter measurements. It is a measure of diameter variation among the fibres of the midside subsample and not through the fleece.

Staple Length.—The mean length of 6 staples.

Crimps per Inch.—The mean number of crimps per inch in 6 measured staples. (The same subsample as used for fibre diameter and staple length measurements).

Body-weight.—Liveweight "off shears", normally in the later part of July.

Neck Score.—Grade score for degree of wrinkledness and folds on the neck.

Side Score.—Grade score for degree of wrinkledness and folds on the side. For side and neck scores, photographic standards are used (Turner *et al.* 1953).

(iv) *Sheep Records and Method of Analysis.*—For the seven fleece characters repeatabilities were estimated from data on 1095 ewes with 1, 2 or 3 records in the years 1955 to 1959, but only 690 of these were used in calculating correlations

among the characters. Repeatabilities and correlations involving the two fold scores and body-weight were estimated from data on 775 ewes with 1 or 2 records in the years 1958 and 1959.

Ewes were grouped according to year of birth, so the final pooled analyses of dispersion were of the form shown in Table 1.

TABLE 1

ANALYSIS OF DISPERSION FOR ESTIMATING PHENOTYPIC PARAMATERS

Source of Variation	Degrees of Freedom	Expectation of Mean Square or Product
Between sheep, eliminating years, within ages	m	$s_{ij} + \frac{m+n}{m} S_{ij}$
Sheep × years, within ages	n	s_{ij}

The phenotypic correlation between two characters, x_i and x_j, measured in the same year was estimated as:

$$\frac{s_{ij} + S_{ij}}{\sqrt{(s_{ii} + S_{ii})\,(s_{jj} + S_{jj})}}$$

This is computationally equivalent to using the pooled sums of squares and products for sheep and sheep × years.

Repeatability, by definition, is the proportion of the variance among individual records due to permanent differences among animals, i.e.

$$\frac{S_{ii}}{s_{ii} + S_{ii}}$$

It can also be thought of as the correlation between records in different years.

By analogy with repeatability, the correlation between two characters x_i and x_j measured in different years was estimated as:—

$$\frac{S_{ij}}{\sqrt{(s_{ii} + S_{ii})\,(s_{jj} + S_{jj})}}$$

III. RESULTS AND DISCUSSION

(a) Means and Coefficients of Variation

To permit comparison with other localities, means and coefficients of variation are listed in Table 2. They were obtained by weighting the means and mean squares for each age group by degrees of freedom. The overall greasy wool weight (8.25 lb), although low by comparison with more favoured sheep

areas, is slightly above the district average. The Commonwealth Bureau of Census and Statistics quotes 8·14 lb as the average cut per head over the period 1955–1960 for adult sheep (including rams and wethers) in the Shire in which the Field Station is situated.

TABLE 2

PHENOTYPIC MEANS AND COEFFICIENT OF VARIATION

Character	Mean	Coefficient of Variation (%)
Greasy wool weight (lb)	8·25	14·0
Per cent. clean scoured yield	54·4	9·3
Clean wool weight (lb)	4·50	17·3
Fibre diameter (microns)	21·0	9·8
Coefficient of variation of fibre diameter (%)	16·9	18·0
Staple length (in.)	3·07	13·3
Crimps per inch	12·2	18·5
Body-weight (lb)	85·0	11·1
Neck score	3·9	23·9
Side score	2·0	41·5

The between-fibres coefficient of variation of diameter (C) is sufficiently low (16·9 per cent.) in relation to mean fibre diameter (21·0 microns) to justify the use of the mean fibre diameter alone in estimating mean fibre cross-sectional area (A). In fact, variations in C would be expected to account for less than 0·5 per cent. of the variance of $\sqrt{A}$.

Turner (1956) reviewed the ranges in published coefficients of variation for seven of the characters studied. The present data fall within or very slightly outside those ranges. They are also comparable with estimates reported by Young, Turner, and Dolling (1960).

(b) Phenotypic Correlations

For testing the significance of the phenotypic correlations in Table 3 the degrees of freedom for sheep only were considered. On this basis the significance of correlations of 0·07 or less is doubtful, while correlations greater than 0·13 can be regarded as well established. In interpreting the correlations it is convenient to group the characters in various ways, as follows:

(i) *Greasy Wool Weight, Yield, and Clean Wool Weight.*—By definition, greasy wool weight (G) is the sum of clean wool weight (C) and other parts not wool (N). From the means and coefficients of variation for G and C in

TABLE 3

PHENOTYPIC CORRELATIONS AMONG CHARACTERS MEASURED IN THE SAME YEAR

Character	Greasy Wool Weight	Per cent. Clean Scoured Yield	Clean Wool Weight	Fibre Diameter	C. of V. of Fibre Diameter	Staple Length	Crimps per Inch	Body-weight	Neck Score	Side Score
Greasy wool weight	..	+ 0·11	+ 0·84	+ 0·06	+ 0·08	+ 0·39	− 0·33	+ 0·15	+ 0·33	+ 0·28
Per cent. clean scoured yield ..	+ 0·11	..	+ 0·56	− 0·02	+ 0·05	+ 0·32	− 0·36	+ 0·02	− 0·03	−0·00
Clean wool weight	+ 0·84	+ 0·56	..	+ 0·05	+ 0·09	+ 0·49	− 0·45	+ 0·13	+ 0·22	+ 0·20
Fibre diameter	+ 0·06	− 0·02	+ 0·05	..	− 0·04	− 0·10	− 0·21	+ 0·11	+ 0·12	+ 0·08
Coefficient of variation of fibre diameter	+ 0·08	+ 0·05	+ 0·09	− 0·04	..	− 0·01	− 0·21	− 0·09	+ 0·00	− 0·03
Staple length	+ 0·39	+ 0·32	+ 0·49	− 0·10	− 0·01	..	− 0·36	+ 0·05	− 0·25	− 0·21
Crimps per inch	− 0·33	− 0·36	− 0·45	− 0·21	− 0·21	− 0·36	..	+ 0·00	+ 0·05	+ 0·09
Body-weight	+ 0·15	+ 0·02	+ 0·13	+ 0·11	− 0·09	+ 0·05	+ 0·00	..	− 0·09	− 0·14
Neck score	+ 0·33	− 0·03	+ 0·22	+ 0·12	+ 0·00	− 0·25	+ 0·05	− 0·09	..	+ 0·65
Side score	+ 0·28	− 0·00	+ 0·20	+ 0·08	− 0·03	− 0·21	+ 0·09	− 0·14	+ 0·65	..

—	Correlations Among First 7 Characters	Correlations Involving Last 3 Characters
Degrees of freedom (sheep)	684	768
Degrees of freedom (sheep × years)	545	420

Table 2 and their correlation (+0·84) it can be inferred that N has a coefficient of variation of the same order as C, and that C and N are positively correlated ($r = +0·29$).

Since per cent. clean scoured yield (Y) is 100 times the ratio C/G, the relationships between Y and G and between Y and C can also be predicted. If it is assumed that the correlations among the logarithms of Y, C, and G are of the same order as those among the original variates, it follows that r_{YG} is approximately +0·07 and r_{YC} approximately +0·60. These values are quite close to those actually calculated from the data (+0·11 and +0·56 respectively). It also follows that the mean clean scoured yield is close to the ratio of the means of C and G.

(ii) *Relationships Among the Components of Clean Wool Weight.*—Turner (1951) defined the components of clean wool weight as:

Smooth body surface area (a function of body weight).

Wrinkling factor (a function of fold score).

Mean fibre cross-sectional area (a function of fibre diameter).

Mean fibre length (a function of staple length).

Mean number of fibres per unit area of smooth skin.

This study provides estimates of the relationships among the first four of these components. However, since no data on the fifth component (density) were collected, it is not possible to apportion the variance of clean wool weight along the lines suggested by Turner (1956). It is still profitable to examine the gross linear correlations. The strongest relationship is that between staple length and clean wool weight ($r = +0·49$). The longer staple is associated with slightly finer wool, somewhat less fold development, and negligible body-weight difference. In contrast, the developed (higher fold score) sheep appear less favourably as shown by the slight, but probably significant, tendency to smaller body size and greater fibre diameter. On the other hand, they do produce somewhat more clean wool. This agrees with the finding of Morley (1955), but is contrary to the observations of other authors reviewed by Turner (1956), who found a sufficiently strong negative relationship with per cent. clean scoured yield to counter an initial advantage in greasy wool weight.

(iii) *Relationship Between Neck and Body Fold Scores.*—If the correlation between the two fold scores is calculated from the sheep components (S_{ij}), r is found to be +0·98. This suggests that the two scores are measures of substantially the same attribute.

This point, and the significance of other relationships among the variates, will be discussed more fully in the second paper of this series when estimates of genetic parameters are presented.

(c) Repeatability and Inter-Year Correlation Coefficients

Estimates of repeatability are shown in Table 4. They agree well with other published estimates. For several of the characters values are intermediate between those of Morley (1951) and Young, Turner, and Dolling (1960).

TABLE 4

ESTIMATES OF REPEATABILITY

Character	Repeatability	95% Fiducial Interval
Greasy wool weight	0·68	0·64 — 0·71
Per cent. clean scoured yield	0·65	0·61 — 0·69
Clean wool weight	0·65	0·60 — 0·68
Fibre diameter	0·53	0·48 — 0·58
Coefficient of variation of fibre diameter	0·45	0·39 — 0·50
Staple length	0·57	0·52 — 0·61
Crimps per inch	0·71	0·67 — 0·74
Body-weight	0·80	0·77 — 0·83
Neck score	0·62	0·57 — 0·68
Side score	0·50	0·43 — 0·57

—	First 7 Characters	Last 3 Characters
Degrees of freedom (sheep)	1087	768
Degrees of freedom (sheep × years)	735	420

The between-year correlations of Table 5 are similar to the phenotypic correlations of Table 3, but generally lower in absolute magnitude. This reflects the fact that within years the correlations among the "steady parts" of the 10 characters are in most cases of the same sign as the correlations between their residuals.

These estimates complete the information required to predict the subsequent productivity of sheep selected on their measured past performance. It is clear that culling for low wool weight (greasy or clean) will raise the flock average cut per head, but at the cost of selecting some of the stronger woolled and more wrinkly animals.

Some degree of selection against these two sources of increased wool weight will usually be warranted, but unless kept to a minimum will drastically curtail the improvement in wool weight. For example, a decision to hold crimp frequency constant would reduce the effective selection differential for clean wool weight to less than half its unrestricted value. Since the price differential corresponding to an increase in crimp frequency is small compared with the coefficient of variation of wool weight, the resulting slight increase in value per pound would be inadequate compensation for the decrease in quantity of wool produced.

TABLE 5

CORRELATIONS AMONG CHARACTERS MEASURED IN DIFFERENT YEARS

Character	Greasy Wool Weight	Per cent. Clean Scoured Yield	Clean Wool Weight	Fibre Diameter	C. of V. of Fibre Diameter	Staple Length	Crimps per Inch	Body-weight	Neck Score	Side Score
Greasy wool weight	..	+ 0·07	+ 0·56	+ 0·04	− 0·09	+ 0·26	− 0·30	+ 0·09	+ 0·33	+ 0·33
Per cent. clean scoured yield ..	+ 0·07	..	+ 0·37	− 0·00	+ 0·06	+ 0·27	− 0·33	− 0·01	+ 0·04	− 0·01
Clean wool weight	+ 0·56	+ 0·37	..	+ 0·04	+ 0·08	+ 0·35	− 0·42	+ 0·06	+ 0·24	+ 0·27
Fibre diameter	+ 0·04	− 0·00	+ 0·04	..	+ 0·01	− 0·08	− 0·17	+ 0·06	+ 0·13	+ 0·07
Coefficient of variation of fibre diameter	− 0·09	+ 0·06	+ 0·08	+ 0·01	..	− 0·01	− 0·19	− 0·07	+ 0·06	− 0·02
Staple length	+ 0·26	+ 0·27	+ 0·35	− 0·08	− 0·01	..	− 0·35	+ 0·02	− 0·24	− 0·17
Crimps per inch	− 0·30	− 0·33	− 0·42	0·17	− 0·19	− 0·35	..	+ 0·01	+ 0·03	+ 0·09
Body-weight	+ 0·09	− 0·01	+ 0·06	+ 0·06	− 0·07	+ 0·02	+ 0·01	..	− 0·08	− 0·09
Neck score	+ 0·33	+ 0·04	+ 0·24	+ 0·13	+ 0·06	− 0·24	+ 0·03	− 0·08	..	+ 0·55
Side score	+ 0·33	− 0·01	+ 0·27	+ 0·07	− 0·02	− 0·17	+ 0·09	− 0·09	+ 0·55	..

	Correlations Among First 7 Characters	Correlations Involving Last 3 Characters
Degrees of freedom (sheep)	684	768
Degrees of freedom (sheep × years)	545	420

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OBSERVATIONS ON CELLULOSE FILM OVER-WRAPPING OF EGG CARTONS UNDER QUEENSLAND CONDITIONS

By B. W. Moffatt, Q.D.A.H. *

SUMMARY

The effect of overwrapping cartons of eggs with MSAT300 Cellulose film was investigated with batches of eggs having a range of initial qualities and stored for one and two weeks at room temperature.

No significant differences in weight loss between overwrapped and unwrapped eggs were observed although there was a trend towards decreased weight loss in the overwrapped group.

Highly significant differences in Haugh Unit values favouring the overwrapped group were observed after one and two weeks of storage.

The interpretation of Haugh Unit rating on break-out in terms of South Queensland Egg Marketing Board grade standards showed an even more definite advantage in favour of overwrapped eggs.

The rapid decline in quality of unwrapped eggs held at room temperatures is very obvious, the rate of decline being of the order of 2.5 Haugh Units per day.

I. INTRODUCTION

The water and carbon dioxide loss from an egg can be minimized by coating the egg with an oil to seal the pores or by packaging it in an airtight container. Both of these methods are used in North America to prevent rapid deterioration of quality. It is obvious that for maximum results the treatments should be carried out as soon as possible after laying. In at least some States of America oiling is carried out on the farm within 24 hr of laying (Skinner 1960). In Queensland many eggs are a number of days old before they reach the egg-grading floor. Oiling is carried out only where eggs are to be stored at low temperatures for several months or for export as "chilled" eggs. The experiment reported here was designed to determine the value of airtight cartons in slowing down the rate of deterioration of quality where eggs are to be sold as "fresh" eggs.

II. PROCEDURE

At present all eggs sold by the South Queensland Egg Marketing Board are packed in cartons. The age of these eggs varies from one to about seven days, and consequently the Haugh Unit values (Haugh 1937) for internal quality of these eggs would be variable. The egg samples used for this experiment were therefore taken in a manner to correspond with this variation.

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In all, eight batches of 72 eggs were examined. They were taken from six different farmers' consignments so that the eggs in each particular batch were from the same source and of the same age. Batches 1 and 2 were one day old at the commencement of the experiment, Batches 3, 4, 5 and 6 were two days old and Batches 7 and 8 were five days old.

Each batch of 6 doz eggs was randomly divided into three groups, A, B, and C, each of 2 doz eggs. Group A of each batch was used as a control and was broken out at the commencement of the experiment, thus making the total control sample 192 eggs. Group B of each batch was divided into two lots of 1 doz each. Both lots were cartoned in the usual manner, but in one lot the cartons were overwrapped with MSAT300 Cellulose film. All Group B eggs were broken out and measured after one week in storage. Group C eggs were treated in the same manner as Group B except that the storage period was two weeks, this being the time for which the South Queensland Egg Marketing Board guarantees eggs sold to retailers. Storage was at room temperature. The average daily maximum temperature during the trial was approximately 85°F.

The overwrapping of the cartons with cellulose film was carried out by hand and the wrapping was heat-sealed to make an airtight pack.

All egg quality measurements were made in Haugh Units, which were later converted to A and B grades used for scoring internal quality on U.S. standards, A grade being 55 Haugh Units and above. Grade A eggs correspond to First quality South Queensland Egg Marketing Board eggs.

III. RESULTS

(i) *Loss of Weight.*—The average weight of each group is shown in Table 1.

TABLE 1

EFFECT OF OVERWRAPPING ON MEAN EGG WEIGHT

Batch	Initial Value	Mean Egg Weight (g) After 1 Week		Mean Egg Weight (g) After 2 Weeks	
		Unwrapped	Overwrapped	Unwrapped	Overwrapped
1	59·17	59·00	59·04	58·17	58·71
2	57·04	56·38	56·50	56·46	56·42
3	58·21	55·54	56·16	55·71	57·21
4	56·81	55·29	56·12	55·21	56·21
5	62·33	60·68	61·62	61·83	62·00
6	59·90	57·96	58·82	58·33	59·00
7	55·46	54·88	55·67	55·12	55·29
8	59·46	59·46	58·38	56·83	58·08
Average	58·55 ± 0·24	57·40 ± 0·34	57·79 ± 0·34	57·21 ± 0·34	57·86 ± 0·34

When the average weights of all Group B eggs (overwrapped and unwrapped) are compared with the initial weights there is a significant weight loss of 0·95 ± 0·34 g per egg ($P < 0·05$). There is, however, no evidence of a further loss of weight during the second week of storage. In all but two cases, the

overwrapped eggs did not lose as much weight as the unwrapped eggs, but the differences are not significant. After one week, the overwrapped eggs were heavier by 0·39 ± 0·48 g and after two weeks by 0·66 ± 0·48 g. The average of the two weeks shows the overwrapped eggs heavier by 0·52 ± 0·34 g.

(ii) *Haugh Unit Values and Grading.*—The average Haugh Unit value of each group is shown in Table 2.

TABLE 2

EFFECT OF OVERWRAPPING ON MEAN HAUGH UNIT VALUE

Batch	Group A Initial Value	Group B (After 1 Week)		Group C (After 2 Weeks)	
		Unwrapped	Overwrapped	Unwrapped	Overwrapped
1	82·6	66·5	72·8	55·4	65·1
2	76·5	53·1	60·6	42·4	59·5
3	76·1	60·0	66·7	47·1	58·1
4	77·0	51·2	64·0	49·7	54·2
5	68·7	51·0	52·6	42·3	47·0
6	62·0	51·6	59·8	46·5	45·5
7	72·6	58·3	60·7	52·4	58·4
8	71·5	53·7	61·1	47·6	58·1
Average	73·38 ± 0·63	55·67 ± 0·90	62·27 ± 0·90	47·92 ± 0·90	55·73 ± 0·90

The Haugh Unit values converted to grades are shown in Table 3.

TABLE 3

EFFECT OF OVERWRAPPING ON GRADE OF EGGS

Batch No.	Group A Initial Grade		Group B* After 1 Week				Group C After 2 Weeks			
			Unwrapped		Overwrapped		Unwrapped		Overwrapped	
	No. A	No. B	No. A	No. B	No. A	No. B	No. A	No. B	No. A	No. B
1	24	0	11	1	11	1	6	6	11	1
2	24	0	6	6	10	2	0	12	10	2
3	24	0	11	1	12	0	2	10	8	4
4	24	0	2	10	12	0	4	8	8	4
5	23	1	3	8	5	7	1	11	4	8
6	20	4	6	6	7	4	2	10	2	10
7	23	1	8	4	10	2	5	7	7	5
8	24	0	5	7	10	2	3	9	7	5
Total	186	6	52	43	77	18	23	73	57	39
Percentage A Quality	96·9 ± 1·25		54·7 ± 5·10		81·0 ± 4·02		24·0 ± 4·35		59·4 ± 5·01	

* Two eggs were broken and could not be measured.

In all but one case the overwrapped eggs were of higher quality than the unwrapped eggs. After one week of storage, the overwrapped eggs were better by 6·59 ± 1·27 units, and after two weeks of storage by 7·82 ± 1·27 units. Averaging the two periods of storage gives a significant difference of 7·21 ± 0·90 units in favour of the overwrapped eggs. These differences in internal quality evaluation are highly significant ($P<0·001$).

It would appear from these results that overwrapping reduced loss in internal quality. At the end of one week, the number of First grade eggs in the overwrapped group was 26·3 ± 6·5 per cent. higher than in the unwrapped group and after two weeks was 35·4 ± 6·6 per cent. higher. The differences in percentage quality are highly significant ($P<0·001$).

IV. DISCUSSION

The average initial Haugh Unit value of eggs in the experiment was 73·38. This is of the order of the Haugh Unit value of eggs handled by the South Queensland Egg Marketing Board as estimated by Moffatt and Byrnes (1961). However, this sample contained 96·9 ± 1·25 per cent. of First quality eggs, which is higher than previous estimates. This would indicate that the sample used was not so variable as would normally be expected in a sample of eggs from this Board. The results expressed here may therefore be slightly better than would be expected from an average sample of eggs from the South Queensland Egg Marketing Board.

The overwrapping would be expected to create a micro-climate with high humidity and high partial pressure of carbon dioxide due to loss of water and carbon dioxide from the egg. Once the humidity and carbon dioxide partial pressure built up within the wrapping, then the loss of water and carbon dioxide from the eggs should be diminished. The weight loss from overwrapped eggs should therefore be less than that from unwrapped eggs. However, although there was a trend in this direction the differences were not statistically significant. A larger sample may be necessary to show these differences as real.

Prior to the experiment it was considered that a difference of 16 Haugh Units in favour of overwrapped eggs would be necessary after two weeks of storage to warrant the use of overwrapping. The differences obtained, although highly significant, fall far short of 16 Haugh Units. However, when the eggs are graded according to South Queensland Egg Marketing Board standards instead of Haugh Units the overwrapped eggs are decidedly better. After two weeks of storage the overwrapped eggs are at least as good as unwrapped eggs after one week of storage. The advantage could be sufficient to warrant overwrapping (provided costs are not excessive), especially where eggs are to be transported long distances, which is often the case in Queensland.

This experiment indicates that overwrapping of eggs does tend to reduce quality loss even though the eggs are more than 24 hr old. Further experiments would be necessary to ascertain whether this applies throughout the various seasons

of the year. It could well be that the greatest benefits are to be obtained in the summer months, when keeping quality is adversely affected by high temperatures. The effectiveness of overwrapping may also be increased by including in the carton a small pellet of dry ice to give a high initial partial pressure of carbon dioxide.

An important point which is obvious in this experiment yet which is not generally recognised in Australia is the rapid decline in quality that takes place when eggs are held at ordinary room temperatures. This experiment was carried out in March, when temperatures are not so high as in midsummer. Even after one week of storage comparable to a similar period in a retail shop, the unwrapped eggs contained only 54·7 per cent. of First quality eggs. The average rate of decline is approximately 2·5 Haugh Units per day. The need for air-conditioned storage is obvious.

V. ACKNOWLEDGEMENTS

The overwrapping of the cartons was carried out by a representative of Austraphane Converting Co., which supplied the MSAT300 Cellulose Film. The statistical analysis was carried out by Mr. A. W. Beattie (Biometrician). The eggs were supplied by the South Queensland Egg Marketing Board.

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WILT OF PEANUT (*ARACHIS HYPOGAEA* L.) IN QUEENSLAND, WITH PARTICULAR REFERENCE TO VERTICILLIUM WILT

By G. S. Purss, M.Sc.Agr. *

SUMMARY

Wilt symptoms encountered in peanuts in Queensland are discussed. It is shown that *Verticillium dahliae* Kleb. is the cause of the common condition and that *Fusarium* sp. is unimportant.

Pathogenicity on peanuts is demonstrated for isolates of *Verticillium dahliae* from tomato, plum and eggplant.

The field distribution of Verticillium wilt has greatly increased in recent years. It is suggested that the change to mechanical harvesting has brought this about.

The association of Verticillium wilt with the better class soil is discussed.

The disease is shown to reduce yield of individual plants by 14-60 per cent. Some of this reduction is due to incomplete filling out of the kernels. The variation in maturity in an affected crop is important.

Methods of control involving crop rotation with emphasis on weed control are suggested.

I. INTRODUCTION

Wilt in peanuts in Queensland has been previously described by Morwood (1945), who found both *Fusarium* sp. and *Verticillium* sp. associated with the disease.

The importance of Fusarium wilt of peanuts was regarded as questionable by Garren and Wilson (1951, pp. 262-324) in a general review of the subject. Records of the disease in both Kenya (McDonald 1933; Humphrey 1939) and Georgia (Miller and Harvey 1932) indicate that while *Fusarium* sp. was the cause, the symptoms were that of a root or crown rot rather than a true vascular wilt. There have been numerous recordings of root or crown rot of peanuts with which *Fusarium* spp. have been associated (Hansford 1934; Ken Knight 1941; Anon. 1939; Anon. 1942; Reichert and Chorin 1942; Anon. 1950).

Verticillium dahliae Kleb., *Verticillium* sp. and *Fusarium* sp. have been reported on peanuts in Asia by Golovin (1937). Verticillium wilt has recently been described in the U.S.A. (Smith 1960).

This paper outlines the result of investigations into the problem in Queensland since 1956.

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II. SYMPTOMS AND ISOLATIONS

There are a number of quite distinct symptom expressions associated with wilt in peanuts. The far more common wilt is characterized by an unusual colouration of the leaf in which chlorotic patches appear in the lamina, particularly around the periphery. This symptom is seen first in the lower leaves, usually about flowering time. The light patches later turn brown, giving the plants a scorched appearance. A true wilt is only noted during excessively dry or hot weather when periods of extreme moisture stress occur. Affected plants usually remain stunted and "mature off" more quickly than normal (Figures 1 and 2).

Fig. 1.—Typical symptoms of Verticillium wilt in peanut plant (left), compared with healthy plant (right).

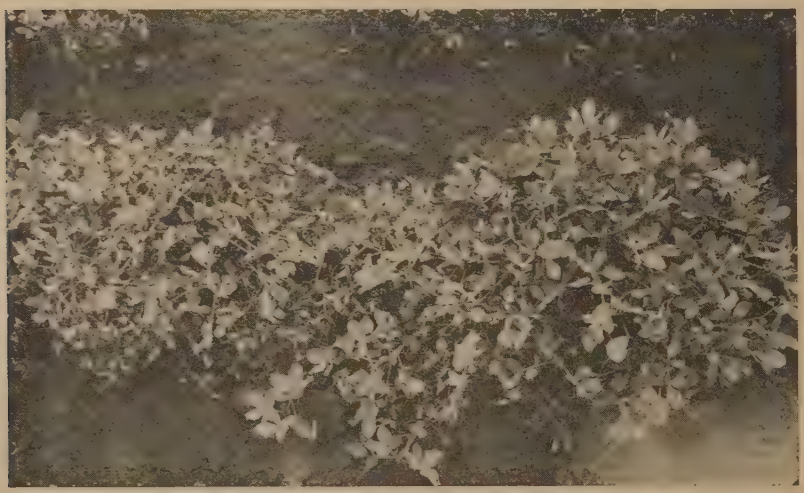

Fig. 2.—Plant on left shows the typical scorched effect of Verticillium wilt.

Except in the most advanced stages the root system appears healthy, but internally there is a pronounced brown to black vascular discolouration extending up the stem and into the leaf bases. Isolations from plants having these symptoms invariably yield *Verticillium* sp.

The second type is characterized by a pronounced wilt of the plant accompanied by yellowing and upturning of the leaves. Although encountered relatively frequently, it affects only isolated plants and is of no economic importance. Plants may be affected at any stage of maturity. In the great majority of cases there is a marked rotting of the tap root, with slight internal discolouration extending up into the crown. Isolations from this condition have yielded *Rhizoctonia solani* Kuehn, *Fusarium* sp. and occasionally *Macrophomina phaseoli* (Maubl.) Ashby. This condition is regarded as more a root rot than a true wilt and is similar to the conditions described in other areas (McDonald 1933; Miller and Harvey 1932).

Plants showing sudden wilt without any other external symptom are occasionally encountered. A brown discolouration of the cortex is apparent through the epidermis but does not extend into the stele. No organism has been consistently isolated from this condition.

In a few isolated instances plants have been observed with symptoms which would normally be regarded as typical of Fusarium wilt. There is a yellowing of the lower leaves and severe wilting, with distinct vascular discolouration extending up the stem and into the leaf bases. *Fusarium* sp. has occasionally been associated with this condition but too infrequently to suggest it as a possible cause.

III. PATHOGENICITY TESTS

Pathogenicity tests on peanut plants have been carried out with four isolates obtained from wilted plants. Two isolates were of *Verticillium* sp. isolated from the commonly occurring condition. The other two isolates were of *Fusarium* sp., one from a plant with pronounced root rot.

Slurry inoculum was prepared from week-old cultures growing on potato dextrose agar. The soil was eased away from the roots of peanut seedlings growing in sterilized soil and the slurry poured down around the plants.

After eight weeks marked symptoms were produced on the plants inoculated with *Verticillium* sp. These in all cases were stunted when compared with uninoculated controls. Leaves were commencing to yellow and some of the plants were developing the typical mosaic pattern on the leaves. Vascular discolouration was apparent in most plants and *Verticillium* sp. was reisolated.

The plants inoculated with *Fusarium* sp. grew as vigorously as the controls. No leaf symptoms were apparent after eight weeks and when the root system was removed from the soil there was no sign of infection.

It is apparent from these tests that *Verticillium* sp. is the cause of the common wilt condition of peanuts in Queensland. Fusarium wilt, if it occurs at all, plays only a very minor role.

IV. DESCRIPTION OF *VERTICILLIUM* SP. FROM PEANUT

The cultural characteristics of the organism were examined, using five separate isolates. These were grown on potato dextrose agar at room temperature. White, fluffy, aerial mycelium developed from the point of inoculation but tended to be restricted towards the margin of the colonies, which were compressed and irregular in shape. After periods of 1–2 weeks black bodies appeared in the substrate, commencing usually around the periphery and point of inoculation. These then gradually appeared over the entire substrate, developing often in concentric rings. After three months three of the isolates appeared black from the presence of these bodies, while in the two other isolates their development was somewhat restricted. Some sectoring was noted in colonies, but although the sectors varied in their production of the black bodies, at no time were they completely absent.

Examined microscopically these bodies appeared to arise by cell division in individual hyphae and were composed of dark-walled thickened cells. They appeared identical with the micro-sclerotia described in detail by Isaac (1949). They were very variable in shape and size, with a range in length from 30 to 210 μ. Non-septate conidia, globose to ovoid in shape, were formed in abundance on potato dextrose agar.

In a series of hyphal tip colonies prepared from two isolates, variation was observed in the number of micro-sclerotia produced. However, no colonies free of these structures were observed.

The growth/temperature relationships of the fungus were determined in a multi-temperature incubator using potato dextrose agar prepared in 4 oz clear bottles. Rate of growth was determined by measurement of the diameter of the colonies, two bottles being used for each determination. The fungus had a minimum just below 5°C and failed to grow at temperatures above 33°C. Optimum growth occurred between 23°C and 26°C. It is obvious from the occurrence of wilt during the hot summer months that *Verticillium* sp. in peanuts is a relatively high-temperature organism.

V. IDENTIFICATION

There has been considerable argument over the validity of the separation of *Verticillium dahliae* Kleb. and *V. albo-atrum* Reinke and Berth. However, the detailed evidence presented by Isaac (1949) and Robinson, Larson, and Walker (1957) indicates that the differences between the two species is constant with regard to micro-sclerotia production and temperature responses. As the peanut organism produced micro-sclerotia and made appreciable growth at 30°C it has been classified as *V. dahliae*. It is pertinent to point out that the type producing micro-sclerotia was the only one encountered during the investigations. It would be indeed confusing if this organism were now grouped with the dark-mycelium strains, an eventuality which would occur if it was classified as *V. albo-atrum*. It seems likely that the micro-sclerotia producing type isolated from peanut by Smith (1960) and described as *Verticillium albo-atrum* is similar to the Queensland organism.

VI. CROSS-INFECTION TESTS

Isolates of *V. dahliae* obtained from plum, tomato and eggplant in Queensland were compared in pathogenicity with the peanut organism on tomato, eggplant and peanut. These isolates all appeared similar with the exception of the one from tomato, which tended to produce micro-sclerotia in greater abundance.

Seedlings of the three test hosts were raised in sterilized soil and inoculated by dipping the roots in a slurry of the test fungus prepared from week-old cultures. The eggplant and tomato plants were removed for examination after 11 weeks and the peanut plants after 17 weeks. Observations were made on general symptom expression but a rating for infection was given on the basis of presence or absence of vascular discolouration. These ratings are listed in Table 1.

TABLE 1

INFECTION RATINGS ON DIFFERENT HOSTS WITH ISOLATES OF *V. dahliae*

Host	Isolate	No. of Plants Inoculated	No. of Plants Infected
Tomato (var. Grosse Lisse) ..	13685 (Tomato)	17	10
	S317 (Plum)	16	0
	K302 (Peanut)	16	3
	13712 (Eggplant)	17	0
	Control (Uninoculated) ..	18	0
Eggplant	13685	17	16
	S317	9	9
	K302	14	14
	13712	12	12
	Control	18	0
Peanut (var. Virginia Bunch) ..	13685	16	12
	S317	16	12
	K302	15	15
	13712	14	14
	Control	15	0

In the tomato host group only those plants inoculated with the tomato isolate showed any visible symptom. These plants were slightly stunted in comparison with the other treatments. The *V. dahliae* reisolates from the infected tomato and peanut groups were similar to the original tomato isolate.

In the eggplant host group stunting of the same order was observed in all isolate groups (Figure 3). The control plants averaged 6·1 in. in height, while the average height of inoculated plants varied from 2·7 in. for the eggplant isolate to 3·4 in. for the plum isolate. *V. dahliae* reisolates which were obtained from each infected group appeared identical, with the exception of the one from eggplant, which showed only slight production of micro-sclerotia.

In the peanut host group considerable stunting occurred with the peanut and tomato isolates (Figure 4), slight stunting with the eggplant isolate and no stunting with the plum isolate or the control. Typical mosaic leaf symptoms were seen in

at least some of the plants in the peanut, tomato and eggplant isolate groups. Reisolations from all the groups yielded apparently identical cultures of *V. dahliae* producing abundant micro-sclerotia.

Fig. 3.—Eggplants inoculated with *Verticillium dahliae* from various hosts. Source, from left to right, uninoculated, peanut, eggplant, tomato, plum.

Fig. 4.—Peanuts inoculated with *Verticillium dahliae* from tomato (left) and peanut (centre). Uninoculated plants on right.

It is apparent from these results that while peanut may be infected with *V. dahliae* from other hosts there is some variation in the relative pathogenicity encountered. Thus the peanut and tomato isolates produced more severe symptoms in peanut than the eggplant or plum isolates did.

Smith (1960) concluded that peanuts in New Mexico were susceptible to *Verticillium* from a wide range of plant material.

VII. FIELD STUDIES OF VERTICILLIUM WILT

(i) *Field Distribution.*—In past years wilt in peanuts occurred in relatively small patches and these were usually associated with stationary threshing sites of previous seasons (Morwood 1953). During the last few seasons infections have become more general, with levels close to 100 per cent. being not uncommon (Figure 5). This change in incidence has coincided with the more general use of mechanical harvesting equipment. Plant debris which was previously destroyed on the thresher sites by burning is now spread evenly over the soil surface. Field evidence suggests that this results in a much wider distribution of the organism responsible for wilt. In this way a relatively unimportant disease has assumed rather serious proportions.

Fig. 5.—View of a field of peanuts showing general infection with Verticillium wilt.

Unlike the incidence recorded in New Mexico (Smith 1960), high rates of infection have not generally been associated with high soil moisture levels. Indeed, during the 1959–60 and 1960–61 seasons, both of which were abnormally dry, the disease was much more widespread than had been previously recorded.

(ii) *Effect of Soil Type and Weed Growth.*—There is great variability in the soil types encountered in the peanut-producing areas of southern Queensland. While Verticillium wilt occurs widely on the more fertile soil types, it is rarely encountered on the poorer class of soil. Nutrition is known to play an important part in the severity of Verticillium wilt in other crops (Garrett 1947; Keyworth and Hewitt 1948; Donandt 1932), the level of nitrogen in the soil being considered of paramount importance. This factor could be the reason for the restriction of peanut wilt to the better soils.

Another factor in this phenomenon could be the higher incidence of weeds susceptible to wilt infection on the better-class soils. On these soils the growth of annual herbaceous weeds is often very prolific, while on the poorer class of soil grass weeds tend to predominate. Close examination has been made of weeds in areas where the disease in peanuts has been severe and Verticillium wilt has been recorded in stinking roger (*Tagetes minuta* L.), Anoda weed (*Anoda cristata* Schlecht.) and Noogoora burr (*Xanthium pungens* Wallr.).

In all three species the disease manifests itself in an uneven yellowing of the lower leaves. This may be accompanied by a stunting and partial wilting of the plants. Brown vascular discolouration is always evident at the base of the stem but may extend up into the leaf bases. *Verticillium dahliae* isolates producing an abundance of micro-sclerotia have been obtained consistently from these plants and appear identical with the peanut organism.

In inoculation tests on peanuts with isolates from *Anoda cristata* and *Tagetes minuta,* typical symptoms of Verticillium wilt are produced.

Both *Tagetes minuta* and *Xanthium pungens* are of widespread occurrence. *Anoda cristata* is more restricted but occurs widely on the better class of soils.

(iii) *Economic Aspects of the Disease*.—Although the presence of Verticillium wilt is widely recognized it is generally accepted as being of little economic importance.

Efforts have been made to assess the effect of the disease by comparing yields of diseased and adjacent healthy plants in affected crops (Table 2). These determinations have necessarily been made in different paddocks each year and this factor, combined with variations in weather conditions, explains the rather wide fluctuations in average yield between seasons.

Samples taken from the second series in the 1960–61 season were used to determine the effect of the disease on kernel weight. In appearance, kernels from diseased plants were rather more wrinkled than those from normal ones. The average weight of five samples consisting of 100 seeds each was 70·1 g for healthy and 63·5 g for diseased. The reduction in yield therefore can be attributed in part to incomplete "filling-out" of the kernels.

TABLE 2

EFFECT OF VERTICILLIUM WILT ON YIELD OF PEANUTS DURING THREE SEASONS

Season	Rainfall (in.) Feb.-April	Average Yield per Plant (g)		Reduction in Yield (%)
		Healthy	Diseased	
1957–58	15·24	133 (12)*	48 (12)	63·9
1959–60	5·38	154 (12)	123 (12)	20·1
1960–61	6·78	77 (25)	66 (25)	14·3
		77 (20)	61 (20)	20·8

* Figures in brackets indicates number of plants used in the determination.

Although the visual effects of the disease appeared much more severe during the dry seasons (1959–60 and 1960–61), the reduction in yield was not nearly so pronounced as in the season of good late summer and early autumn rains (1957–58).

The reduction in yield even at the lowest level of 14 per cent. is of considerable economic importance. The variation in maturity in a crop resulting from the disease is of equal significance. This often requires the grower to harvest 2–3 weeks earlier than the optimum time, with consequent loss in yield and quality from the healthy bushes.

VIII. CONTROL OF VERTICILLIUM WILT

The value of crop rotation in the control of this disease has been advocated (Morwood 1945). General observations confirm that where rotations are judiciously practised the disease is kept in reasonable check. However, there have been occasions when wilt has assumed serious proportions on land seldom cropped to peanuts. On at least one of these occasions susceptible weeds were found in abundance. Where the disease has been severe it would be wise to pay particular attention to control of herbaceous weeds throughout the rotation.

Reports indicate that *V. dahliae* can survive in the soil for at least four years (Anon. 1954), so rather than adopt the usual maize/peanut rotation, a period to grass in severely infected paddocks could be an advantage. With the change in peanut harvesting methods, whereby diseased plant residue is disseminated much more effectively, the need for this longer type of rotation has become more apparent.

IX. ACKNOWLEDGEMENTS

The assistance of Miss B. L. Winks in determining the growth/temperature relationships of *Verticillium dahliae* is gratefully acknowledged. Thanks are also due to the many interested farmers who allowed observations to be made on their properties.

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CONTROLLED ATMOSPHERE STORAGE OF QUEENSLAND GROWN GRANNY SMITH APPLES

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SUMMARY

Investigations conducted over a period of eight years demonstrated that controlled atmosphere storage can be used successfully with Granny Smith apples.

Fruit retained its firmness better in the presence of carbon dioxide, and carbon dioxide did not encourage soggy breakdown. However, superficial scald increased as the proportion of carbon dioxide was raised, particularly in fruit harvested earlier than mid-April.

The most satisfactory atmosphere was found to be 5% oxygen, but the cost involved in removing carbon dioxide is high.

A satisfactory alternative if a scald inhibitor is used is a mixture of 16% oxygen and 5% carbon dioxide.

I. INTRODUCTION

It was demonstrated by Kidd and West (1935) that the refrigerated storage life of certain varieties of English grown apples could be appreciably extended by storage in atmospheres containing less oxygen and more carbon dioxide than are normally present in the atmosphere. The results of Kidd and West with gas, or controlled atmosphere, storage were confirmed by a number of workers with a wide range of apple varieties (Smock and Van Doren 1939, 1941; Huelin and Tindale 1947; Mandeno and Padfield 1953; Martin and Cerny 1956).

With the increasing necessity to extend the marketing period of Queensland apples because of expansion of the industry, investigations were commenced in 1952 to study the effects of controlled atmosphere storage on the Queensland grown Granny Smith variety. Progress in these experiments was briefly reported in the Annual Reports of the Queensland Department of Agriculture and Stock for the years 1952-53 to 1959-60. More extended progress reports by Stevenson have appeared in *Queensland Fruit and Vegetable News*, a weekly newspaper published by the Committee of Direction of Fruit Marketing. In addition, the 1955 investigations were fully reported by Stevenson (1957) as part of a report on apple cool storage investigations for that year, and the 1956 investigations were reported by Stevenson and Blake (1961) as part of a study of the use of chemical compounds in inhibiting superficial scald on stored Granny Smith apples.

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II. 1952 EXPERIMENTS

(i) *Objective.*—To study the effects of controlled atmosphere storage on keeping quality.

(ii) *Fruit.*—Fruit for the experiment was obtained from a commercial packing shed in the Stanthorpe district. It had been picked in early April.

(iii) *Pre-storage Treatments.*—The fruit was graded for size, wrapped in oiled paper wraps containing 15% mineral oil and packed in standard 1 bus timber cases. It was then railed to Brisbane, where it was stored in the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Four cases of uniformly sized fruit from each of two growers were stored in each of five storage atmospheres, viz. normal air storage; 5% oxygen plus 2·5% carbon dioxide; 5% oxygen plus 5% carbon dioxide; 5% oxygen with less than 1% carbon dioxide present; and 2·5% oxygen with less than 1% carbon dioxide present.

In commercial controlled atmosphere stores, it has been a common practice to hold fruit at a temperature several degrees higher than that normally used for normal cool storage as it is considered that controlled atmosphere storage makes the fruit more susceptible to low-temperature injury. For this reason, the storage cabinets were fitted with heating elements which maintained the fruit temperature at 38°F, while the control fruit was held at the normal storage temperature of 34°F.

After the fruit was loaded into the experimental gas-tight containers, the atmospheres were allowed to build up to approximately the concentrations required and were then adjusted with nitrogen, oxygen and carbon dioxide from an external source. Regular checks on concentration were made during the storage period with an Orsat gas analyser and necessary adjustments made with nitrogen and carbon dioxide cylinders.

Removals from storage were made on September 2, 1952 (Removal 1) and October 6, 1952 (Removal 2). After each removal was made, the atmospheres in the cabinets were re-adjusted to the required concentration.

On each occasion that fruit was removed from the storage cabinet it was held for seven days at atmospheric temperatures to simulate normal marketing delays and then examined for storage disorders and firmness. Firmness readings were made with the $\frac{7}{16}$ in. plunger of a Magness penetrometer on opposite sides of five fruit from each case.

(v) *Results.*—The results are summarized in Table 1.

There was very little wastage due to mould and soggy breakdown.

Fruit from the first removal had significantly less scald than that from the second removal. While there were no significant differences in scald incidence between atmospheres, there is a trend in the results which suggests that the amount of scald present increased with concentration of carbon dioxide in the storage atmosphere.

TABLE 1

DATA ON DEFECTS AND FIRMNESS OF APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE. 1952 EXPERIMENT

Treatment	Superficial Scald (%)	Total Wastage (%)	Firmness
Control			
Removal 1	1·7	2·5	18·9
Removal 2	10·6	15·7	26·0
5% O_2+2·5% CO_2			
Removal 1	9·1	11·0	21·8
Removal 2	18·8	24·2	26·5
5% O_2 + 5% CO_2			
Removal 1	11·2	12·7	27·0
Removal 2	24·1	32·7	26·5
5% O_2 +< 1% CO_2			
Removal 1	3·2	4·0	29·0
Removal 2	8·0	16·2	26·0
2·5% O_2 +< 1% CO_2			
Removal 1	1·4	2·5	30·1
Removal 2	13·8	18·9	26·6

Superficial scald :

Removal 1 significantly less than Removal 2 (5% level).

No significant differences between atmospheres.

Total wastage :

No analysis of variance carried out.

Firmness :

Removal 1—5% oxygen + 5% carbon dioxide ; 5% oxygen + less than 1% carbon dioxide ; 2·5% oxygen + 1% carbon dioxide all significantly firmer than Control and 5% oxygen + 2·5% carbon dioxide.

Removal 2—No significant differences.

Control—Removal 2 significantly firmer than Removal 1 (1% level).

5% oxygen + 2·5% carbon dioxide—Removal 2 significantly firmer than Removal 1 (1% level).

5% oxygen + 5% carbon dioxide—Difference not significant.

5% oxygen + less than 1% carbon dioxide—Difference not significant.

2·5% oxygen + less than 1% carbon dioxide—Removal 1 significantly firmer than Removal 2 (5% level).

Firmness determinations on the experimental fruit were extremely high. A number of significant differences were revealed by an analysis of variance (Table 1).

III. 1953 EXPERIMENT

(i) *Objective.*—In view of the work of Tindale and Huelin (1939) and Padfield (1950), who reported a decrease in the incidence of superficial scald with increase in the maturity of the fruit, the 1953 experiment was designed to compare the effects of controlled atmosphere storage on fruit of two stages of maturity and from trees of different ages.

(ii) *Fruit.*—Granny Smith apples were obtained from each of four growers in the Stanthorpe district and comprised fruit from young and old trees at two different picking dates, April 4 (Maturity 2) and April 14 (Maturity 3). The maturity designations Maturity 2 and Maturity 3 are used so that the results can be compared with those obtained by Stevenson and Watkins (1961) with normal air storage of this variety over a number of different picking dates over a more extended period.

(iii) *Pre-storage Treatments.*—The fruit was wrapped in oiled paper wraps containing 15% mineral oil, packed and railed to Brisbane, where it was stored in gas-tight containers at the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Three half-bushel cases of each category of fruit were stored at 34°F in three different atmospheres, viz. normal air storage; 5% oxygen with less than 0·5% carbon dioxide; and 5% oxygen plus 2·5% carbon dioxide.

The carbon dioxide concentration in the storage atmosphere was maintained at the required level by passing the gas mixture in the chambers through vessels containing aqueous sodium hydroxide. Oxygen levels were maintained constant by means of a small cock, open to the external air, with an aperture which could be adjusted to allow small amounts of air to enter the chamber, thus replacing any oxygen used up in the respiration processes of the fruit. Regular checks of the storage atmospheres were made by means of an Orsat gas analysis apparatus.

Removals of fruit from the cabinets were made on October 19 (Removal 1), November 16 (Removal 2) and December 8 (Removal 3).

After each removal was made, the atmospheres in the cabinets were re-adjusted to the required concentrations by means of external cylinders of nitrogen, oxygen and carbon dioxide.

The fruit, after removal from store, was held at atmospheric temperatures for seven days to simulate normal marketing delays and was then inspected for storage disorders.

(v) *Results.*—The results are summarized in Table 2.

Fruit from the first removal had significantly less soggy breakdown than that from the second removal, which in turn had significantly less than that from the third removal. Fruit stored in an atmosphere containing 5% oxygen plus 2·5% carbon dioxide had significantly less soggy breakdown than that stored in normal atmospheres.

TABLE 2

DATA ON DEFECTS AND FIRMNESS OF APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE. 1953 EXPERIMENT

Treatment	Severe Superficial Scald (%)	Total Superficial Scald (%)	Soggy Breakdown (%)	Total Wastage (%)	Firmness
Control					
Maturity 2	11·2	23·8	18·7	42·9	11·0
Maturity 3	8·0	16·5	26·8	45·4	10·8
Removal 1	4·7	17·9	3·6	22·6	11·9
Removal 2	10·5	24·6	24·8	46·9	10·6
Removal 3	13·5	18·0	39·8	62·9	10·2
$5\%O_2 + < 0{\cdot}5\%CO_2$					
Maturity 2	14·3	33·4	16·5	40·4	11·5
Maturity 3	14·3	26·5	20·1	48·7	11·5
Removal 1	11·2	28·2	4·8	28·6	12·8
Removal 2	17·8	37·6	15·6	51·3	11·0
Removal 3	13·8	23·9	34·4	52·8	10·6
$5\%O_2 + 2{\cdot}5\%CO_2$					
Maturity 2	29·4	47·7	13·7	48·1	12·2
Maturity 3	23·9	40·2	14·2	55·9	12·3
Removal 1	20·4	38·5	3·8	38·9	12·9
Removal 2	28·8	49·1	16·0	60·5	12·1
Removal 3	30·7	44·2	22·0	56·8	11·7

Soggy breakdown :

Removal 1 significantly less than Removal 2 (1% level).

Removal 2 significantly less than Removal 3 (1% level).

5% oxygen + 2·5% carbon dioxide significantly less than Control (5% level).

Superficial scald :

Severe—Removal 1 significantly less than Removals 2 and 3 (5% level).

Control and 5% oxygen + less than 0·5% carbon dioxide significantly less than 5% oxygen + 2·5% carbon dioxide (1% level).

Total—Removals 1 and 3 significantly less than Removal 2 (1% level).

Maturity 3 significantly less than Maturity 2 (1% level).

Control significantly less than 5% oxygen + less than 0·5% carbon dioxide (1% level).

5% oxygen + less than 0·5% carbon dioxide significantly less than 5% oxygen + 2·5% carbon dioxide (1% level).

Total wastage :

No analysis of variance carried out.

Firmness :

No analysis of variance carried out.

Fruit from the second pick had significantly less superficial scald than that from the first pick. The trend in the 1952 experiment, which suggested that the amount of superficial scald increased as the concentration of carbon dioxide

in the storage atmosphere increased, was confirmed in this experiment. The fruit stored under normal atmospheres had significantly less scald than that stored in an atmosphere containing 5% oxygen with less than 0·5% carbon dioxide present. This atmosphere, in turn, resulted in significantly less scald than when the fruit was stored in an atmosphere containing 5% oxygen plus 2·5% carbon dioxide.

No analysis of variance was carried out on total wastage, which was composed mainly of superficial scald and soggy breakdown. Since large differences are necessary for significance it is unlikely that maturity had any effect on the amount of total wastage present. However, there was an increase in wastage with increase in the length of the storage period.

Although no analysis of variance was carried out on firmness, fruit held in controlled atmospheres appeared to be firmer than that stored under normal atmospheres. The results also indicate that the firmness of the fruit increased as the carbon dioxide content of the atmosphere was increased.

IV. 1954 EXPERIMENT

(i) *Objective.*—To study the effect of controlled atmospheres not previously used, viz. 16% oxygen plus 5% carbon dioxide, which is easily obtained in a sealed chamber by the natural respiration of the fruit and can be easily maintained by ventilation with normal air, and 10% oxygen plus 2·5% carbon dioxide, which can be fairly easily maintained by mechanical means and is an atmosphere intermediate between those used previously and the easily maintained 16% oxygen plus 5% carbon dioxide atmosphere.

(ii) *Fruit.*—Granny Smith apples were obtained from each of four different growers in the Stanthorpe district and comprised fruit from old and young trees in each orchard at each of two picking dates, April 2 (Maturity 2) and April 14 (Maturity 3).

(iii) *Pre-storage Treatments.*—The fruit was wrapped in oiled paper wraps containing 15% mineral oil, packed into cases and railed to Brisbane, where it was stored in the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Three half-bushel cases of each category of fruit were stored at 34-36°F in three storage atmospheres, viz. normal air storage; 10% oxygen plus 2·5% carbon dioxide; and 16% oxygen plus 5·0% carbon dioxide.

The controlled atmosphere fruit was sealed in gas-tight containers and the atmospheres were allowed to build up approximately to the required storage atmospheres and then adjusted with nitrogen and carbon dioxide from external cylinders. During the storage period, regular checks on the concentrations in the containers were made with an Orsat gas analysis apparatus and any necessary adjustments made with nitrogen and carbon dioxide from external cylinders.

Removals of fruit from the storage cabinets were made on October 4 (Removal 1), November 9 (Removal 2) and December 6 (Removal 3).

TABLE 3

DATA ON DEFECTS AND FIRMNESS OF APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE. 1954 EXPERIMENT

Treatment	Mould (%)	Soggy Breakdown (%)	Superficial Scald (%)	Total Wastage (%)	Firmness
Control					
Maturity 2	4·3	12·8	13·3	27·4	13·1
Maturity 3	7·2	9·3	7·5	24·8	12·5
Old Trees	4·5	9·8	9·6	24·1	12·9
Young trees	7·0	12·3	11·2	28·1	12·7
Removal 1	3·3	0·0	11·5	15·8	14·0
Removal 2	7·0	6·1	11·1	25·2	13·3
Removal 3	6·8	27·1	8·6	37·3	11·1
$10\%O_2 + 2{\cdot}5\%CO_2$					
Maturity 2	2·9	0·4	24·3	27·7	15·9
Maturity 3	4·0	0·0	6·6	13·7	15·5
Old Trees	2·7	0·4	15·0	19·8	15·4
Young trees	4·3	0·1	15·9	21·5	16·0
Removal 1	2·2	0·1	9·9	14·3	16·2
Removal 2	3·1	0·2	18·7	23·3	16·4
Removal 3	5·1	0·3	17·8	24·4	14·5
$16\%O_2 + 5\%CO_2$					
Maturity 2	2·8	0·4	38·3	41·0	17·0
Maturity 3	3·0	0·2	16·3	19·8	16·7
Old trees	1·6	0·2	25·2	26·8	16·9
Young trees	4·2	0·4	29·5	34·1	16·7
Removal 1	2·4	0·0	24·6	27·4	17·3
Removal 2	2·8	0·2	27·5	30·6	18·1
Removal 3	3·5	0·8	29·9	33·3	15·1

Mould :

No analysis of variance carried out.

Soggy breakdown :

No analysis of variance carried out.

Superficial scald :

Control significantly less than 10% oxygen + 2·5% carbon dioxide and 16% oxygen + 5% carbon dioxide (5% level).

Maturity 3 significantly less than Maturity 2 (1% level).

Total wastage :

Old trees significantly less than young trees (5% level).

Maturity 3 significantly less than Maturity 2 (1% level).

10% oxygen + 2·5% carbon dioxide significantly less than Control (5% level) and 16% oxygen + 5% carbon dioxide (1% level).

Removal 1 significantly less than Removal 2 (1% level).

Removal 2 significantly less than Removal 3 (5% level).

Firmness :

16% oxygen + 5% carbon dioxide significantly firmer than 10% oxygen + 2·5% carbon dioxide (1% level).

10% oxygen + 2·5% carbon dioxide significantly firmer than Control (1% level).

Maturity 2 significantly firmer than Maturity 3 (5% level).

Removal 1 and Removal 2 significantly firmer than Removal 3 (1% level).

After each removal of fruit from the storage chambers, the atmospheres were returned to the required concentrations with nitrogen and carbon dioxide from external cylinders.

The fruit, after removal from store, was held at air temperature for seven days to simulate normal marketing delays and then inspected for disorders.

(v) *Results.*—The results are summarized in Table 3.

Mould incidence was comparatively slight and an analysis of variance was not carried out. There was less mould in the fruit held in controlled atmospheres than in fruit held in air but the difference was small. Mould was approximately twice as common in fruit from young trees as in fruit from old trees. There was also an increase in this disorder with increase in the length of the storage period.

The incidence of soggy breakdown in fruit in the controlled atmospheres was negligible irrespective of maturity, tree age, composition of storage atmosphere or length of the storage period. The control fruit, however, showed a considerable increase of the disorder with increase in the length of the storage period. Carbon dioxide concentration in the storage atmosphere had a marked effect on the amount of superficial scald present. Fruit from the first pick had significantly more scald than that from the second pick. The length of the storage period and tree age had no significant effect on the amount of the disorder.

There was a highly significant decrease in total wastage with increase in the maturity of the fruit. In addition, fruit from old trees showed significantly less wastage than that from young trees. The effects of atmosphere were most significant, fruit from both of the controlled atmospheres having less wastage than that from the control. However, of the two atmospheres used, the 10% oxygen plus 2·5% carbon dioxide had significantly less wastage than the 16% oxygen plus 5% carbon dioxide, mainly because of the lower incidence of superficial scald. There was a significant increase in the incidence of wastage with increase in the length of the storage period.

Fruit from the first pick was significantly firmer than that from the second pick. There was a significant increase in firmness with increase in the carbon dioxide content of the storage atmosphere. No significant differences in firmness existed between fruit from the first and second removals, but fruit from both these removals was significantly firmer than that from the third removal.

V. 1955 EXPERIMENT

(i) *Objective.*—To determine the effects of later picking dates on the incidence of superficial scald in controlled atmosphere storage.

(ii) *Materials and Methods.*—These have been reported by Stevenson (1957).

(iii) *Results.*—The results reported by Stevenson (1957) are summarized here as follows:

Mould wastage was greater in fruit from young trees than in fruit from old trees. Fruit stored in a 16% oxygen plus 5% carbon dioxide atmosphere had less mould than fruit in normal air storage, and an atmosphere of 10% oxygen plus 2·5% carbon dioxide showed no difference from the control.

The incidence of soggy breakdown was low. None occurred in fruit from the first removal but there was an increase with length of storage period. Age of tree had no effect on the incidence of the disorder. Increase in carbon dioxide concentration reduced soggy breakdown in both picks.

An increase in superficial scald was found with an increase in the carbon dioxide concentration in fruit from the first pick. Neither the length of the storage period nor the age of the trees had any effect on the incidence of scald.

Total wastage increased with length of the storage period. Fruit from the second pick had less wastage than that from the first pick. Storage atmosphere had no significant effect on total wastage.

The firmness of the fruit decreased as the storage period lengthened. Fruit from both the controlled atmospheres was firmer than that from air storage. That stored in the 16% oxygen plus 5% carbon dioxide atmosphere was about ½ lb firmer than that stored in the 10% oxygen plus 2·5% carbon dioxide atmosphere. In the higher carbon dioxide atmosphere the fruit was about 2 lb firmer than the control fruit. Firmness was not affected by maturity or by tree age.

VI. 1956 EXPERIMENT

(i) *Objective.*—To study the inhibiting effect of DPA on superficial scald in storage.

(ii) *Materials and Methods.*—These have been reported in detail by Stevenson and Blake (1961).

(iii) *Results.*—The results of the 1956 experiment (Stevenson and Blake (1961) may be summarized as follows so far as the effects of controlled storage atmospheres are concerned:

There was a highly significant increase in mould with increase in the length of the storage period, and fruit from the first pick had significantly less mould than that from the second pick.

Very little soggy breakdown was encountered in the experiment irrespective of whether the fruit was wrapped, unwrapped or treated with DPA. However, in fruit stored under normal atmospheres there was a definite increase of the disorder with increase in the length of the storage period and, in addition, fruit from the first pick had more soggy breakdown than fruit from the second pick.

The effect of storage atmosphere on superficial scald incidence was highly significant and was related to the length of the storage period. In the first and second removals, fruit from normal air storage and a 5% oxygen atmosphere had significantly less scald than that from either a 16% oxygen plus 5% carbon dioxide or a 11% oxygen plus 10% carbon dioxide atmosphere. In the third removal, fruit stored under 5% oxygen had slightly more scald than that held under normal atmospheres, but this may have been due to inadequate removal of carbon dioxide (Stevenson and Blake 1961). Fruit held under 16% oxygen plus 5% carbon dioxide was more affected by the disorder than fruit stored in either air or 5% oxygen, but was significantly less affected than fruit held under 11% oxygen plus 10% carbon dioxide.

Very little superficial scald was present when DPA dips were used and up to 5% carbon dioxide was present in the storage atmosphere. A concentration of 10% carbon dioxide in the storage atmosphere resulted in a greater amount of scald present even when DPA dips were used. However, the use of oiled paper wraps in addition to a DPA dip reduced this scald incidence to almost zero. Because of the small amount of scald present in the experimental fruit treated with DPA, the effect of time of picking and length of the storage period on the storage behaviour of fruit treated with this compound could not be analysed statistically.

When oiled paper wraps alone were used, considerable scald was present, and the increase of the disorder with longer storage periods and with high carbon dioxide concentrations in the storage atmosphere were highly significant. Fruit from the first removal had less scald than that from either of the two later removals. Fruit from the second pick was less affected than that from the first pick.

The effect of storage atmosphere on total wastage was highly significant, less wastage being present in fruit stored under 5% oxygen than in the other atmospheres at the third removal. In the first and second removals both the 5% oxygen and normal air-stored fruit were significantly less affected than that in the other two storage atmospheres. However, further increase in the length of the storage period greatly increased wastage in the fruit stored under normal atmospheric conditions. For all removals the 16% oxygen plus 5% carbon dioxide atmosphere was significantly better than the 11% oxygen plus 10% carbon dioxide atmosphere.

The effect of storage atmosphere on firmness of fruit was highly significant. Air-stored fruit was not as firm as fruit stored in an atmosphere of 5% oxygen, which in turn was not as firm as that stored in the 16% oxygen plus 5% carbon dioxide or the 11% oxygen plus 10% carbon dioxide atmospheres. Under an atmosphere of 5% oxygen, fruit in oiled paper wraps was significantly softer than that treated with DPA irrespective of whether the treated fruit was wrapped or not. There were also some effects on firmness due to DPA dips when fruit was stored under atmospheres of either 5% oxygen or 16% oxygen plus 5% carbon dioxide.

VII. 1957–1959 EXPERIMENTS

(i) *Objective.*—To test consumer and market reaction to Granny Smith apples stored under controlled atmospheres.

(ii) *Fruit.*—In each year experimental fruit was selected in four Stanthorpe district growers' packing sheds from fruit picked in mid-April, which earlier experiments had shown was the earliest suitable stage of maturity for controlled atmosphere storage.

(iii) *Pre-storage Treatments.*—The fruit was wrapped in oiled wraps containing 15% mineral oil, railed to Brisbane, and stored in the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Seventy-two 1 bus cases were stored in gas-tight containers at 34°F. The storage atmosphere selected was 5% oxygen without any carbon dioxide. Although the presence of carbon dioxide results in firmer fruit, it was considered desirable to exclude carbon dioxide because it tends to increase the incidence of superficial scald, particularly in early-picked fruit, and growers could be expected to pick some fruit earlier than the middle of April. DPA could not be used as a scald inhibitor because of public health restrictions on its use.

The experimental chambers were sealed, and prior to sealing, trays of commercial grade flake sodium hydroxide were enclosed to remove carbon dioxide given off by the respiration of the fruit. After sealing, the atmospheres were allowed to build up to the approximate oxygen level and were then adjusted by nitrogen from an external cylinder. During the storage period regular checks were made with an Orsat gas analysis apparatus and any necessary adjustments made with oxygen and nitrogen from external cylinders.

The chambers were opened in mid-December each year and the fruit forwarded to the Brisbane Wholesale Fruit Market for sale through the normal marketing channels.

(v) *Results.*—The response of both the consumer and the retailer was very satisfactory. Premium prices were paid for the fruit, which was in excellent condition. Visual examination on the market floor revealed very few disorders.

VIII. DISCUSSiON

Throughout the eight years of experimental work surveyed in this paper, the Queensland grown Granny Smith apple proved well suited to controlled atmosphere storage.

Fruit stored in controlled atmospheres was firmer than that held under normal air-storage methods. It was practically free from soggy breakdown, and superficial scald was unimportant when fruit of suitable maturity was stored in an atmosphere containing little or no carbon dioxide.

It was shown that fruit intended for controlled atmosphere storage should not be picked before mid-April, as fruit harvested earlier is extremely susceptible to superficial scald, particularly in atmospheres containing carbon dioxide.

Though the presence of carbon dioxide in the storage atmosphere resulted in firmer fruit, the increased incidence of superficial scald due to the gas generally precludes its use. The most satisfactory atmosphere was found to be 5% oxygen. To maintain this atmosphere requires removal of the carbon dioxide liberated by the fruit. On a commercial basis this necessitates the use of a scrubbing device, involving considerable expense and labour.

The tests reported by Stevenson and Blake (1961) on inhibition of superficial scald in Granny Smith apples by chemical means have shown that diphenylamine and 6 ethoxy 1,2 dihydro 2,2,4 trimethylquinoline give good control of the disorder, and the use of one or the other would permit fruit to be stored in an atmosphere containing carbon dioxide without appreciable development of scald. The most satisfactory storage atmosphere for fruit treated with a scald inhibitor would be one containing a mixture of 16% oxygen and 5% carbon dioxide. This atmosphere would be easy to maintain in the storage chamber since it can be obtained readily by controlled ventilation. The use of an inhibitor must await the clearance of a suitable chemical by public health authorities. 6 ethoxy 1,2 dihydro 2,2,4 trimethylquinoline has been cleared in the United States for use as either a preharvest spray or a post-harvest dip treatment of apples for human consumption.

IX. ACKNOWLEDGEMENTS

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ACCUMULATION OF SALT IN IRRIGATED NORTH QUEENSLAND TOBACCO SOILS

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SUMMARY

High chloride content of leaf is common in furrow irrigated flue-cured tobacco leaf from the Burdekin Irrigation Area of North Queensland.

Soil chloride content to 30 in. is low at the beginning of the season but a build-up occurs during the season. This accumulation is greatest in the top 6 in. of the row or "hill" position, which is also a zone of extensive root development. The furrow shows little build-up in surface horizons.

Below 12 in. little variation occurs under either row or furrow.

It is considered that plant uptake results from soil chloride which is concentrated in the rows by lateral and upward movement of irrigation water containing moderate amounts of chloride, usually between 30 and 40 p.p.m. Cl.

I. INTRODUCTION

It has been noted over a number of years that the chloride content of irrigated flue-cured tobacco from certain areas of North Queensland is higher than desirable, with values of 2–3 per cent. Cl in leaf frequently encountered and with occasional samples containing up to 6 per cent. Cl in the lugs. Plant growth is not affected, but the detrimental effect of high chloride content in relation to quality, including leaf burn, has long been recognised (Attoe 1946; Myhre, Attoe, and Ogden 1956).

In many cases reported in the literature this chloride content has been attributed to fertilizers containing chloride, but such fertilizers are not used in this area for tobacco. Although recent work (Colbran and Green 1961) points to the importance of soil fumigants in halide uptake, chloride added to the soil in irrigation water has been recognized as important in some areas. For example, Peele, Webb, and Bullock (1960) investigated irrigation waters and their effect on leaf quality of flue-cured tobacco in South Carolina.

The greater proportion of the tobacco crop in the Burdekin area is planted out in spring between mid-August and mid-September. Harvesting generally commences in early November and is completed by the end of December. Early summer storms may occur but frequently the crop is grown completely under irrigation. The area has an average annual rainfall of 25-35 in., most of which is expected in the wet-season months of January, February and March. Evaporation

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rates during the growing season are high, particularly in October and November, when an average evaporation of approximately 8 in. per month has been measured over the past three years.

The pattern of water usage under furrow irrigation in the district varies somewhat, but commonly the first major watering of the crop is made in the planting furrows. It is common practice to withhold water for 4–6 weeks from that time. As the plant approaches maturity, water is applied as required, usually at weekly intervals from prior to first pick. In general, if appreciable rainfall does not occur average irrigation water application is in the vicinity of 20 in. Depending on the technique adopted, an unknown amount of this water runs off and actual penetration varies considerably. In most cases water penetration following irrigation does not exceed 18 in. in depth.

Because of the prevalence of blue mould and the danger of wind damage following possible early summer storms, it is considered necessary in the area to have well-formed beds. Plant rows are usually 42–48 in. apart, with each bed between 18 and 24 in. wide and bed height 5–7 in. above the bottom of the furrow. Soil fumigation about one month prior to planting is accepted practice in the area, with ethylene dibromide the most commonly used fumigant.

II. PROCEDURE AND METHODS

Investigations involved taking soil samples from various field positions and depths over a number of growing seasons. For three seasons, on the selected trial area, randomized sampling sites were taken and at each site soil samples were obtained from the row (hill), midway between rows (furrows) and on the slope of the hill as indicated in Figure 1. Samples were obtained for 0–3 in. and 3–6 in. zones, at 12 in. and in some cases at 18 in. and 24 in. Samples from the row were obtained approximately midway between plants in the row. Complete cross-section samples discussed later were also obtained from this position. For the 1956 crop, detailed leaf analyses were carried out for the experimental area. Soil samples were collected in sealed jars prior to irrigation, and moisture determinations made. Chloride was determined on a suspension of 105°C oven-dry soil by electrometric titration. Samples were allowed to stand with occasional stirring for a minimum of 30 min and titrated with N/71 silver nitrate using a silver/silver chloride electrode and a quinhydrone reference half-cell after the method of Best (1929). In the soils under examination, end point drift is not a problem. Results are expressed as chlorine (p.p.m.) in oven-dry soil.

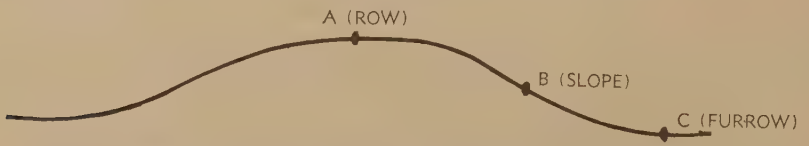

Fig. 1.—Diagram showing positions at which samples were taken in 1954, 1955 and 1956.

TABLE 1

SOIL CHLORIDE CONTENT FOR ROW, SLOPE AND FURROW, 1955 SEASON
(p.p.m. Cl in oven-dry soil (mean values))

Sampling Date	Nov. 2			Nov. 29			Dec. 19		
Position	0–3 in.	3–6 in.	12 in.	0–3 in.	3–6 in.	12 in.	0–3 in.	3–6 in.	12 in.
A—Row	80	57	17	60	35	14	56	36	16
B—Slope	18	17	14	28	19	12	53	31	16
C—Furrow	22	16	13	23	19	10	28	28	13
	A >> B, C	A >> B, C	A > C	A >> B, C	A >> B, C	A > C	no significant difference		

>> at 1% level. > at 5% level.

Leaf samples were dried at approximately 80°C and the midrib removed. The dried leaf-web material was ground to a fine state in a blender and a suspension prepared for chloride determination as in the soil analysis.

III. OBSERVATIONS

(a) Soils

Soil chloride figures quoted refer to mean values for a number of sampling sites in the selected experimental areas.

For the 1954 and 1955 seasons, work was carried out on a soil of the Burdekin Group at Claredale.

During the 1954 season, the chloride content of the 0–3 in. zone of the row rose to 95 p.p.m. Cl early in December, while this zone in the furrow reached a maximum of 65 p.p.m. Cl. For both row and furrow at 12 in., a content of 45 p.p.m. Cl was found.

Results of the 1955 season's work are shown in Table 1. The 0–3 in. zone of the row position contained 80 p.p.m. Cl early in November, while this zone in the furrow contained 22 p.p.m. Cl. Later in the season, sample variability occurred but the mean value for the row position was still twice that of the furrow in the 0–3 in. zone. At 12 in. all positions contained less than 17 p.p.m. Cl and remained below this level throughout the season. Mean values for adjacent fallow land receiving no irrigation water remained less than 23 p.p.m. Cl at 0–3 in. and less than 18 p.p.m. Cl at 12 in. throughout this period.

For the 1956 season, work was carried out on a Burdekin Series soil at Millaroo. Soil samples were obtained as previously and plant samples were taken from the growing crop at the time of each soil sampling.

As shown by Table 2, the maximum level of soil chloride in the 0–3 in. zone of the row was 70 p.p.m. Cl on December 17, while the furrow for this 0–3 in. zone contained 25 p.p.m. Cl. At 12 in., variation throughout the season was not great. Subsequent to the sampling of December 17, over 4 in. of rain fell (December 20–23) and this resulted in a marked decrease in chloride content in the 0–3 in. row position at the next sampling. At this stage three picks had been taken from the crop. Harvesting is usually completed before the onset of the wet season and chloride levels in the row can usually be expected to remain high through the harvest period.

TABLE 2

SOIL CHLORIDE CONTENT FOR ROW AND FURROW, 1956 SEASON

(p.p.m. Cl in oven-dry soil (mean values))

Sampling Date	Oct. 29	Nov. 12	Nov. 19	Nov. 26	Dec. 3	Dec. 10	Dec. 17	D. 2ec8
0–3 in.—Row ..	32	28	31	29	26	45	70	28
0–3 in.—Furrow ..	32	23	30	24	16	30	25	28
12 in.—Row	11	20	22	27	22	15	20	2ç
12 in.—Furrow ..	11	18	20	19	16	19	16	20

Leaf samples were obtained from a number of plants in the trial area at each soil sampling date and composite samples of each leaf position analysed. Chloride content of 6th and 10th leaf positions is shown in Table 3. These figures indicate the characteristic higher chloride content of the lower leaf position and in both cases show a marked increase in leaf chloride content coinciding with the increase in the soil chloride for the 0–3 in. zone of the rows in mid-December.

TABLE 3

LEAF CHLORIDE CONTENT OF GROWING PLANT, 1956 SEASON

(% Cl)

Sampling Date	Nov. 12	Nov. 19	Nov. 26	Dec. 3	Dec. 10	Dec. 17
6th leaf	2·1	2·1	2·0	2·0	2·0	4·0*
10th leaf	1·4	1·5	1·8	1·9	1·8	3·3
p.p.m. Cl 0–3 in. soil (row)	28·0	31·0	29·0	26·0	45·0	70·0

* Ripe leaf, ready for harvest.

For the 1960 season, a general survey was carried out on eight farms in the district. In August, before planting, soil chloride was found to be less than 20 p.p.m. Cl in all cases. Towards the end of the season, before rainfall, 0–6 in. samples from the rows showed levels generally greater than 50 p.p.m. Cl and in a few cases were greater than 100 p.p.m. Cl. At 18 in. the content remained below 20 p.p.m. Cl throughout with the exception of one farm, where some samples were slightly higher.

A number of detailed profile cross-sections through the row were also obtained. Figure 2 shows a cross-section of a Clare Series soil taken two days after the ninth irrigation of the area and about the time of fifth pick. Figure 3 shows a similar cross-section for a Burdekin Series soil. This soil had received over 2 in. rainfall some days prior to sampling. The area had received seven waterings and was sampled about the time of the third pick. Although the concentration in the better-drained Burdekin Series soil is less, a similar trend is observed in each case. The highest chloride content is found in the actual crest of the bed. Profile cuts in the row between plants have shown the most extensive

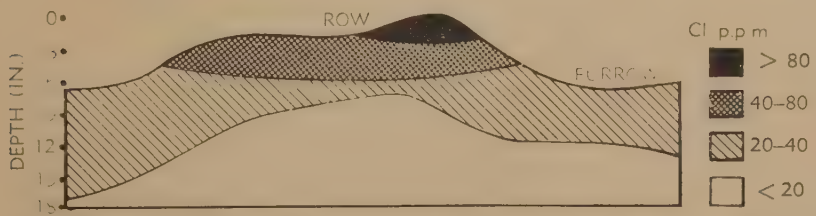

Fig. 2.—Diagram showing chloride distribution in row in Clare Sandy Loam.

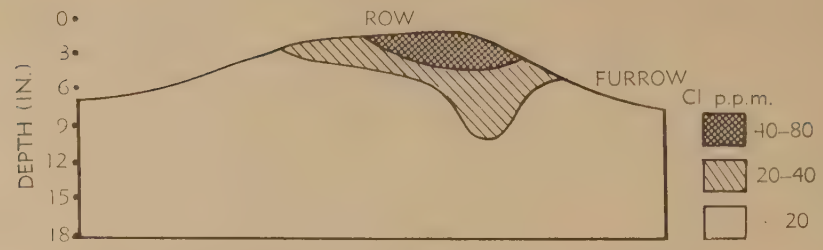

Fig. 3.—Diagram showing chloride distribution in row in Burdekin Fine Sand.

root development away from the main stem to be in the 0–6 in. zone. In Figure 2 this root development was in the zone shown to contain 40–80 p.p.m. Cl. These diagrams also indicate the difficulty in obtaining consistent auger samples for chloride measurement in an area.

Table 4 shows the chloride content of leaf samples from the areas where these profile sections were obtained.

TABLE 4

CHLORIDE CONTENT OF LEAF FROM AREAS OF PROFILE CROSS-SECTION, 1960 SEASON

(% Cl)

Soil Type	Pick 2	Pick 4	Pick
Clare Sandy Loam (Fig. 1) ..	3·6	2·7	1·8
Burdekin Fine Sand (Fig. 2) ..	2·8	2·7	2·2

(b) Water

In the Burdekin River system, heavy summer monsoon flood run-off is expected between January and April, with little rain falling over the catchment area in winter and spring. During the period of crop irrigation and prior to the onset of the wet season, river flow is light and in dry years may cease completely from early summer. Chloride content of the river water is low during the period of flood run-off. During the tobacco-growing season, there is fluctuation in chloride content from year to year, but with the exception of 1958 the chloride content of irrigation water applied to the tobacco crops since 1954 has been between 30 and 40 p.p.m. Cl. There is evidence to suggest that the highest content can be expected following isolated early-summer storm run-off from certain tributaries.

Table 5 shows the chloride content of river water over a number of years for the September-December irrigation period and also for two wet-season periods. For the irrigation period, the total soluble solids content of the water usually lies in the range of 170–210 p.p.m., mainly as calcium and magnesium bicarbonates.

TABLE 5

CHLORIDE CONTENT OF BURDEKIN RIVER IRRIGATION WATER

Period	No. of Samples	Average Cl (p.p.m.)	Maximum Cl (p.p.m.)
1954 (September–December) ..	8	21	24
1955 (September–December) ..	10	38	45
1957 (September–December) ..	17	32	38
1958 (September–December) ..	9	50	53
1959 (February–April)	5	16	..
1959 (September–December) ..	17	32	36
1960 (January–April)	10	13	..
1960 (September–December) ..	20	30	35

IV. DISCUSSION

From the programme cited here and from a number of samples taken from various farms throughout the area, it is evident that in the majority of cases the level of soil chloride at the end of the wet season (April) and through to the commencement of the main tobacco-growing season (September) is low through the profile at least to a depth of 30 in. Burdekin River water has low chloride content during flood run-off but for the main irrigation period (September-December) in most years contains 30–40 p.p.m. Cl. Increase in soil chloride commences following irrigation and this increase is mainly in the top 3 or 6 in. of the row position. This soil increase and the chloride taken up by the crop can be accounted for by the chloride added in irrigation water.

Wadleigh and Fireman (1946) in field plot experiments in the U.S.A. showed accumulation of salt in the rows with very high amounts in the surface inch of this zone. In laboratory experiments, Bernstein and Fireman (1957) demonstrated the pattern of salt movement and accumulation in the beds of furrow-irrigated soil, with salinity highest in the surface of the bed at the centre. It is considered that such a pattern exists in this case, though modified by irregularities in bed shape. In general, with the irrigation techniques used in the district, water movement at least in the upper 3–4 in. of the row is lateral and upwards only. Chloride applied in irrigation water remains in this zone and is concentrated by successive waterings. Effective downward water movement and leaching occur in the furrow and at depth beneath the row. Below 12 in. little variation is found throughout the season. This pattern of salt movement has been indicated by the profile samples from row and furrow over a number of seasons and confirmed by actual cross-section sampling.

The zone of chloride accumulation has also been found in field observations in this district to be a zone of extensive fine root development. Chouteau (1959) found that irrigated Paraguay tobacco on alluvial soils in the Dordogne had over 98 per cent. of the fine root system in the top 30 cm, and most of this

was in the top 20 cm. He further found most of the roots to be beneath the plant and in the rows, with comparatively few roots between the rows. In the Burdekin area, the main concentration of roots is found in the top 6 in. of the row. Below a depth of one inch or so, the zone of higher salt content and root development remains above wilting point except for short periods. As the moisture content of the zone is depleted, although still within the available moisture range, the increase of chloride concentration of the soil water is considered to be an important factor in plant chloride uptake. Wadleigh and Fireman (1948), with reference to cotton, pointed out that when a salt concentration occurs in the rows, the main water removal is from under the furrows, where, because of the lower salt content the work required to remove moisture from the soil is least. However, for the tobacco crops investigated here, the root concentration under the furrow is not great and the major part of the moisture will be obtained from the beds. Furthermore, although the relative concentration of salt is greater here, it is still not a high salt concentration by physiological standards. For the samples investigated, the maximum salt content measured in soil moisture approaching wilting point of 6 per cent. moisture would be responsible for an increase of less than 2 atmospheres in the osmotic pressure of the soil solution and this is not considered to seriously affect the ability of the plant to obtain water and nutrients, including chlorine, from this zone. It is to be remembered that the problem is not one of a salt toxicity but one of the luxury consumption of chlorine. This does not have an adverse effect on plant growth at the concentrations encountered but is important in the quality of cured leaf.

The appreciable amount of chlorine removed from the soil by the plant will affect soil chloride content in the various zones, but no measure of this removal pattern is available. It is considered likely that the greater part of the high leaf chloride content results from uptake by the extensive fibrous root system in the 0–6 in. zone of the rows where chloride has been concentrated from irrigation water by lateral and upward movement and the absence of leaching.

V. ACKNOWLEDGEMENTS

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TECHNICAL NOTES

A NOTE ON EGG QUALITY IN SOUTHERN QUEENSLAND

Investigations were conducted in 1959-60 to appraise the quality of eggs as received and marketed by the Egg Marketing Board operating in South Queensland with the objective of indicating the benefit to be expected from improved handling of eggs prior to marketing.

Random samples of approximately 1,000 eggs graded for internal quality by candling and for weight were taken direct from the grading machines in five sampling periods each of one week spread over 13 months. All First quality sample eggs were broken out on the day of sampling and internal quality measured in Haugh Units. Internal faults were recorded and the eggs regraded according to faults and Haugh Unit value. Samples of Second grade eggs were taken on three occasions and regraded by a check egg grader.

Quality of Eggs Received

A reconstruction of the quality of eggs as received appears in Table 1 together with air temperature data.

There is a tendency for the quality to decline as the temperature rises, but modifying factors occur. For instance, egg quality is much lower in January than in March, despite similar prevailing temperatures, probably because by March many of the hens laying in January would have been replaced by young stock laying eggs of higher quality.

The analysis of Second quality eggs shows the same effect of temperature on quality. The percentage of stale eggs is lowest where the holding temperature is lowest. The high percentage of "other faults" in the January test is attributed largely to an increase in eggs that showed embryonic development due to the high temperature.

TABLE 1

RECONSTRUCTION OF THE QUALITY OF EGGS AS RECEIVED BY THE EGG MARKETING BOARD

(a) *Overall Quality*

Test No.	Week Ending	Average Daily Maximum Temperature (°F)	Percentage First Quality	Percentage Second Quality
1	13.viii.59	74·7	82·3	17·7
2	15.i.60	83·0	73·8	26·2
3	11.iii.60	85·4	82·3	17·7
4	15.vii.60	65·2	91·1	8·9
5	30.ix.60	76·5	83·4	16·6

(b) *Analysis of Second Quality Eggs*

Test No.	Percentage Intake Second Quality	Faults Expressed as a Percentage of All Eggs Received					
		Stale	Cracked	Blood and Meat Spots	Ruptured Membranes	Stained	Other Faults
1	17·7	*	*	*	*	*	*
2	26·2	13·3	7·0	1·5	0·4	1·1	2·9
3	17·7	*	*	*	*	*	*
4	8·9	2·0	4·2	2·0	0·3	0·3	0·1
5	16·6	6·9	6·6	1·8	0·3	0·9	0·1
		Faults expressed as a Percentage of Second Quality Eggs					
1	17·7	*	*	*	*	*	*
2	26·2	50·8	26·7	5·7	1·5	4·2	11·1
3	17·7	*	*	*	*	*	*
4	8·9	22·5	47·2	22·5	3·4	3·4	1·0
5	16·6	41·6	39·8	10·8	1·8	5·4	0·6

* Not sampled.

Quality of Eggs Marketed

Eggs graded as First quality contained from 3·8 to 17·1 per cent. of Second quality eggs, staleness being the most common fault (Table 2). The accuracy of the graders (Table 3) varied with the quality of the eggs received (Figure 1). The trend towards increased accuracy as the tests progressed could be due to the appointment of a check egg grader after the first test or to extra care being taken by the graders. The accuracy of detecting blood and meat spots by candling was very low (Table 3).

TABLE 2

ESTIMATE OF THE QUALITY OF EGGS MARKETED

Test No.	No. Sampled	Percentage Regraded First Quality	Percentage Regraded Second Quality	Average Haugh Units of 1st Quality Eggs	Faults Expressed as a Percentage of First Quality Eggs			
					Stale	Blood Spots	Meat Spots	Other Faults
1	1069	88·6	11·4	69·4	8·1	1·3	0·9	1·1
2	1019	82·9	17·1	68·2	12·7	0·4	0·9	3·1
3	1002	90·0	10·0	70·4	6·9	0·2	0·3	2·6
4	1000	96·2	3·8	75·5	2·0	0·8	0·9	0·1
5	1000	91·8	8·2	69·3	6·4	0·6	1·1	0·1

TABLE 3

(*a*) GRADERS' ACCURACY IN CLASSIFYING SECOND QUALITY EGGS

Test No.	Percentage Intake Second Quality	Percentage Graded Second Quality	Percentage Accuracy
1	17·7	7·1	40·1
2	26·2	11·0	42·0
3	17·7	8·6	48·5
4	8·9	5·4	60·6
5	16·6	9·2	55·4

(*b*) GRADERS' ACCURACY IN DETECTING BLOOD AND MEAT SPOTS

Test No.	Percentage Blood and Meat Spots in all Eggs Received	Percentage Blood and Meat Spots in First Quality Eggs	Percentage Accuracy
1	*	2·34	..
2	1·5	1·3	20·0
3	*	0·5	..
4	2·0	1·7	21·0
5	1·8	1·7	14·4

* Not sampled.

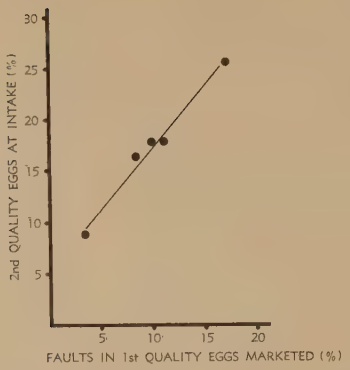

Fig. 1.—Relationship between quality of eggs and accuracy of grading.

Week-end Carryover

Eggs held over from Friday until Monday morning for grading were consistently lower in quality than other First quality eggs, the most common fault being staleness.

Discussion

The tests indicated that South Queensland's subtropical climate is responsible for much deterioration in egg quality, especially in the summer months. Though eggs are normally despatched to retailers within 48 hr of receipt by the Egg Marketing Board, some may be five or six days old by this time and in the summer would have been held for at least portion of the time at an average daily temperature reaching a maximum of 74 to 85°F. Quality is much higher when the holding temperature does not exceed 65°F. As the accuracy of the graders depends largely on the quality of the eggs on receipt, it is even more important that the quality of eggs received for grading be improved by lowering the holding temperature in some way. There is therefore a definite need for air-conditioned egg-holding rooms on farms.

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A SELF-PROPELLED COMBINE HARVESTER FOR EXPERIMENTAL PLOTS

The essential requirements for a combine harvester for experimental plots of grain and seed crops are (1) that large quantities of grain are not retained in elevators, (2) that the machine is capable of thorough cleaning in a short time, (3) that the machine has a high degree of manoeuvrability, and (4) that the machine can harvest most of the important grain and seed crops included in the experimental programme.

Following is a detailed description of a prototype harvester developed to meet the above requirements as closely as possible and based on plot yields of 10-50 lb of grain from individual harvested areas up to 5 ft wide.

Description

General.—The machine is a self-propelled combine harvester of conventional arrangement, i.e. the crop is cut with a sickle bar, conveyed to a threshing drum by means of an auger and elevator, and the grain separated from the straw by means of reciprocating screens.

Fig. 1.—Side view of combine harvester

Sickle Bar and Elevator.—This is a conventional assembly, similar to that in use on several of the standard combine harvesters. The mown material is carried by means of an auger to the base of a centrally placed scraper-type

elevator, which delivers the material to the threshing drum. The movement of the material towards the auger is assisted by a rotating wooden slat reel. Provision is made for adjusting the height and forward position of the reel axis in relation to the sickle bar.

The reel is driven from the sickle bar, auger and elevator drive assembly, so its speed of rotation is related directly to the speed of the threshing mechanism. In certain conditions it is preferable for the reel speed to be related to the ground speed, and if this were required slight modification to the drive arrangements would permit the reel to be driven by one of the front wheels.

The sickle bar is fitted with comb-type fingers 24 in. long. Other types of fingers may be fitted if required.

The height of the sickle bar and elevator assembly may be regulated hydraulically, the range of adjustment measured at the sickle bar being from ground level to 3 ft from the ground. Removable panels are provided in the elevator duct and at one end of the auger to facilitate cleaning.

The effective cutting width is 5 ft, but it would be possible to fit a wider sickle bar, if required, and the entire front assembly could if necessary be replaced by a different type of collecting equipment.

Drum and Concave.—The drum is of open construction, 16 in. in diameter and fitted with eight rubber-faced bars, similar to those used in certain of the Allis-Chalmers combine harvesters. Metal rasp bars could be fitted if required. The clearance between the drum and the concave may be regulated between zero and 2 in. by changing the position of the drum shaft bearings. The drum is driven by a roller chain from the main drive countershaft and the sprockets on the countershaft and the drum shaft are readily interchangeable to provide variations in drum speed. Provision is made for adjusting the chain tension to suit different sizes of sprockets.

The concave is fitted with two rubber-faced bars. Provision is made for regulating the clearance between the lower of these bars and the drum. Additional bars, or bars of a different type, could readily be fitted if required.

The drum is provided with a hinged cover. The concave is hinged at the forward end and secured by two bolts at the rearward end so that it may be released and swung downwards away from the drum. Drum and concave are then fully exposed for cleaning.

Separation and Cleaning.—The threshed material is delivered by the drum into a reciprocating "weather-board" straw shaker. The grain falls through large louvred D-shaped perforations in the shaker and is delivered to the forward end of a screen with rectangular louvred perforations. It passes through this screen and through a lower screen with small D-shaped perforations and is collected in a removable tray carried beneath the machine. Two of these trays are provided so that at the end of each plot the full tray may be immediately replaced with an empty one. The trays are suitably shaped for pouring the contents into bags.

Any occasional ears or pods which may be incompletely threshed are collected in a removable tray at the rear of the machine, and they may if required be passed through the machine a second time. This arrangement replaces the conventional "repeat" mechanism of standard threshers, which has not been included in the design because of the extra cleaning involved when the machine is to be used for harvesting pure seed.

An adjustable canvas curtain is hung beneath the cover of the straw shaker to prevent the threshed material from being discharged at the rear of the machine before the grain has been fully separated from the straw. This is particularly important when small plots are being harvested because under these conditions there is little accumulation of straw on the straw shaker.

The straw shaker cover itself is held in position by four spigots and can readily be removed to facilitate cleaning of the shaker and screens. The shaker and the screens may themselves be withdrawn for cleaning.

Fig. 2.—Rear view of combine harvester

Aspiration.—Any light impurities are separated from the grain by means of a conventional centrifugal fan mounted forward of the screens. The volume of air may be regulated by restricting the size of the fan inlets, and the direction of the air flow may be controlled by means of movable baffles in the fan outlets.

Bagging Attachment for Large Plots.—The grain-collecting tray beneath the thresher has a capacity of approximately one bushel, which is more than sufficient for normal trial plots. If the machine is to be regularly used for larger plots or

for harvesting seed-increase areas, the collecting tray may be replaced by an elevator which delivers the grain to a bin with bagging outlets. The elevator is provided with removable panels to facilitate cleaning.

Fig. 3.—Harvesting an experimental plot of dwarf grain sorghum

Air-blast Cleaning Equipment.—A high-volume, low-pressure air supply is provided by a rotary vacuum pump operated in the reverse direction. The pump is mounted on the framework of the machine and driven from the main engine drive, which may be engaged as required by means of a jockey pulley tensioner applied to the drive belt. A suitable length of rubber hose, fitted with a tubular steel nozzle, is attached with a standard hose coupling to the pump outlet.

Power Unit.—A Ford 4-cylinder watercooled petrol engine is mounted above the straw shaker cover. This engine is designed to develop approximately 15 b.h.p. (12 hr rating) at a speed of 2000 r.p.m. The engine speed is regulated by a governor.

Drives to Threshing Mechanism.—The fan and the air pump are driven directly from the crankshaft extension by means of conventional V-belt drives. The remainder of the threshing mechanism is driven from a countershaft which is itself driven from the crankshaft extension by means of a double V-belt drive. This drive may be engaged as required by means of a movable jockey pulley which tensions the belts.

The chain drive from the countershaft to the drum shaft has been described. The sickle bar and elevator assembly, the straw shaker and screen eccentric shafts and the hydraulic pump for operating the sickle bar and elevator assembly lift are all driven by V-belt drives from the countershaft.

Chassis and Ground Drive.—The machine is built on a welded steel chassis and is carried on four pneumatic-tyred wheels, the sizes of which are quoted below in the list of dimensions. The drive is transmitted to the front wheels and the machine is steered by the rear wheels.

The machine is fitted with a "Dunstan" hydraulic transmission unit. The hydraulic pump forming part of this unit is driven from the main countershaft and activates a hydraulic motor mounted beneath the machine in the region of the front axle.

The pump and the motor are linked by flexible hydraulic pressure hose. The rotation of the motor is transmitted to the front wheels through two differentials. The drive is transmitted between the differentials by means of a roller chain. This type of transmission provides an infinite variation of ground speed between zero and 4 m.p.h. in forward and reverse direction and eliminates the clutch and gearbox of conventional drive trains. The maximum ground speed may be changed by fitting different sprockets in the drive to the second differential.

In the neutral position the transmission acts as a brake. A conventional hydraulic brake system is fitted to the front wheels for use in emergency should the transmission fail.

Controls.—The machine is controlled from a platform mounted on the off side above the front wheel. In the sitting position the operator's head is about 8 ft from the ground, giving him a clear view of the cutting mechanism. The machine is steered with a conventional steering wheel and linkage to the rear wheels. Forward speed is controlled by means of a lever and quadrant, the required speed being selected by engaging the lever in the appropriate notch in the quadrant.

The engine speed is regulated at the governor itself, but a hand control is provided within the reach of the operator to reduce the speed to a slow idle. The engine is started by means of a self-starter controlled from the operator's position. There is a foot pedal to operate the hydraulic brakes on the front wheels.

The drive from the engine to the countershaft is engaged by a lever at the side of the operator's position. The hydraulic jack operating the adjustment of the sickle bar and elevator assembly is also controlled from the operator's position.

Dimensions.—General dimensions are as follows:

Overall length	15 ft
Overall width	6 ft
Overall height	7 ft 6 in.
Wheelbase	7 ft 9 in.
Track	4 ft
Ground clearance	8 in.
Turning circle	29 ft
Weight	3,486 lb
Ground speed	0–4 m.p.h.
Tyre sizes—	
Front (driving wheels)	7·00 in. x 20 in.
Rear (steering wheels)	6·00 in. x 16 in.
Cutting width	5 ft
Cutting height	Ground level to 3 ft
Drum width	29 in.
Drum diameter	16 in.

Performance

The harvester has successfully harvested field experiments with soybeans and grain sorghums. It has also been used for threshing maize and *Dolichos biflorus*, the latter being a fine vining legume with seed somewhat similar to lentils.

The machine has been used to harvest soybean varietal trials in which it was necessary to harvest pure seed. It was found that two men could efficiently clean the harvester in approximately 10 min.

Credits

The specifications upon which the design of this machine was based were decided at a joint discussion held at Kingaroy between officers of Agriculture Branch, Department of Agriculture and Stock; Commonwealth Department of Primary Industry; and the principals of Kingaroy Engineering Works. Throughout the manufacture of the machine the authors assisted the manufacturers in a consultative capacity. The detailed design of the machine and its construction were undertaken by Kingaroy Engineering Works, Kingaroy.

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PESTICIDE TAINT TRIALS IN TOBACCO

Taint trials must be carried out before recommending pesticides for use in Queensland tobacco fields. Smith (1961) has recorded trials carried out in the 1952–1954 seasons, and since then a further four trials have been completed at Inglewood (1958–59 and 1959–60) and Parada (1959–60 and 1960–61). The results of these 8 trials (combined in Table 1) and experience gained have established definite requirements and methods for this type of work:

(1) It is essential to use only first quality crops, as leaf quality is an important factor in the detection of taints due to pesticides.

(2) The materials are applied at commercial strengths to complete cover within 7 days of harvesting, as in Queensland tobacco fields spraying to control pests and harvesting may be concurrent.

(3) The use of screens is required to prevent cross-contamination by spray drift.

(4) BHC is a satisfactory standard treatment for inclusion in taint trials.

(5) Provision must be made to ensure that not less than 3 lb of cured leaf will be available for each sample, and treatments are replicated 6 times.

(6) Each sample is wrapped separately in moisture-proof viscose film, numbered and forwarded without the key to a testing panel consisting of personnel experienced in handling tobacco leaf.

Notes on panel testing, which have been provided, are as follows:

"Samples are set out without any attempt to place like sorts together. All samples are retained in their original wrappings, and are replaced on every occasion that a test is carried out.

Categories are Nil, Slight, Distinct, and Distinct plus.

Each member of the testing panel examines the samples by nose. Particular attention is paid to the butts and the opening up of the main body of the sample, which is normally well compressed. An initial requirement is to have a reasonable appreciation of the normal aroma or smell of leaf from the particular district in which the taint trial leaf has been grown. A sample from the stock of leaf from that district should therefore be used as an outside check.

Confusion may result if too many samples are attempted at the one session, particularly if there is a wide range of taint levels. It is advisable to allow at least 6 hours between sessions.

When the panel has completed its examination, analyses of records sheets are made. These show up major differences of assessment among members of the panel, which can understandably occur when residues of distinct taints bias the assessment of the succeeding sample. In practice,

there are no major differences in about 75 per cent. of first-test records. Inconsistencies are checked 24 hours later by all panel members without access to previous records.

When setting up a panel, sensory judgment is confirmed by smoking tests. Once the panel becomes experienced the amount of checking with smoking tests can be reduced, but is still necessary where doubt exists."

By definition, leaf classified as distinctly tainted is objectionable when used alone or in blends, and slight tainting implies the presence of undesirable flavours which can be masked by blending (Smith 1961); and furthermore, testing is to an appreciable extent subjective. Evaluation of trial results therefore can be no more than dichotomy (see Table 1).

TABLE 1

RESULTS OF TAINT TRIALS, 1952–1961

Material	No. of Trials	No. of Samples Tested	Taint Results : No. of Samples with—				Percentage of Samples with Distinct Taints
			Nil	Slight	Distinct	Distinct plus	
Aldrin	2	12	8	4	Nil	Nil	Nil
BHC	3	18	1	1	15	1	**88·9**
Chlordane	2	12	1	3	8	Nil	**66·7**
DDT	1	6	Nil	5	1	Nil	16·7
DDT + lead arsenate	1	3	Nil	3	Nil	Nil	Nil
Dieldrin	4	24	15	9	Nil	Nil	Nil
Endrin	3	15	6	8	1	Nil	6·7
"Guthion"	1	6	Nil	Nil	1	5	**100·0**
"Kelthane"	4	21	6	14	1	Nil	4·8
Lindane	7	32	8	15	9	Nil	28·1
Parathion	1	3	2	1	Nil	Nil	Nil
Sevin	1	6	Nil	4	2	Nil	33·3
Toxaphene	2	12	4	Nil	8	Nil	**66·7**
"Telodrin"	3	18	8	6	4	Nil	22·2
TTC	1	3	Nil	Nil	3	Nil	**100·0**
Untreated	7	42	25	14	3	Nil	7·1

"Guthion" is now added to the list of materials which, because of taint, cannot be recommended for use in Queensland tobacco fields. Previously Smith (1961) had listed BHC, chlordane, toxaphene and TTC.

REFERENCE

SMITH, W. A. (1961).—Tobacco leaf-pest control investigations, 1949-1955. *Qd J. Agric. Sci.* 18:33-56.

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